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Accelerated Experimentation

Pneumatic Conveying

Reducing Tank Corrosion

Open Process Automation

Valves

January 2023

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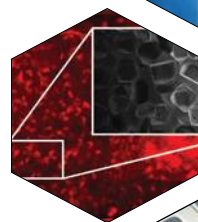
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EDITORS

DOROTHY LOZOWSKI
 Editorial Director
 dlozowski@chemengonline.com

GERALD ONDREY (FRANKFURT)
 Senior Editor
 gondrey@chemengonline.com

SCOTT JENKINS
 Senior Editor
 sjenkins@chemengonline.com

MARY PAGE BAILEY
 Senior Associate Editor
 mbailey@chemengonline.com

GROUP PUBLISHER

MATTHEW GRANT
 Vice President and Group Publisher,
 Energy & Engineering Group
 mattg@powermag.com

AUDIENCE DEVELOPMENT

JOHN ROCKWELL
 Managing Director, Events & Marketing
 jrockwell@accessintel.com

JENNIFER McPHAIL
 Marketing Manager
 jmcphail@accessintel.com

GEORGE SEVERINE
 Fulfillment Manager
 gseverine@accessintel.com

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HEADQUARTERS

40 Wall Street, 16th floor, New York, NY 10005, U.S.
 Tel: 212-621-4900
 Fax: 212-621-4694

EUROPEAN EDITORIAL OFFICES

Zeilweg 44, D-60439 Frankfurt am Main, Germany
 Tel: 49-69-9573-8296
 Fax: 49-69-5700-2484

CIRCULATION REQUESTS:

Tel: 800-777-5006
 Fax: 301-309-3847
 Chemical Engineering, 9211 Corporate Blvd.,
 4th Floor, Rockville, MD 20850
 email: clientservices@accessintel.com

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 9211 Corporate Blvd., 4th Floor
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Editor's Page

Transitioning into the new year

This past year was one of the best in a decade for the chemical process industries (CPI), according to the American Chemistry Council's (ACC; Washington, D.C., www.americanchemistry.com) year-end report [1]. The report details that output of U.S. chemical producers grew by 3.9% and chemical industry capital spending grew 9.0% to \$33.5 billion in 2022. Much of the investment went toward capacity expansions, upgrades and sustainability projects, such as for recycling and development of lower-emissions technologies. The gains this past year were made despite serious headwinds, including supply-chain disruptions, energy price fluctuations and worldwide economic uncertainties due largely to the war in Europe, as well as ongoing effects from the pandemic.

As these challenges continue to varying degrees, and with the economy struggling with inflation, Martha Moore, ACC chief economist and author of the report [1] says "We anticipate a shallow recession beginning in early 2023 followed by recovery in the latter part of the year." Relatively healthy balance sheets for U.S. chemical companies are cited in support of the expected recovery.

Transformation

We have seen for some time now that trends in the CPI include numerous topics in support of sustainability goals including: carbon reduction through abatement, such as carbon capture; reduction of fossil-fuel use and advances in alternate energy sources; decarbonization through use of alternative feedstocks; electrification of processes; a focus on circularity, such as through advanced recycling, and digitalization for efficiency and to stay competitive. Readers will likely have noticed that these topics tend to dominate the latest news on our website (www.chemengonline.com). We have, in fact, expanded our e-newsletter offerings to include more of these sustainability topics. We have also initiated an e-newsletter focused solely on developments around hydrogen.

In its 2023 Chemical Industry Outlook, Deloitte (www.deloitte.com) writes about the transformation of the chemical industry, which it says is "needed to meet the clear imperatives for circularity, decarbonization and sustainability." The Deloitte report breaks down the industry trends into four segments: (1) Sustainability and innovation; (2) Portfolio transformation; (3) Supply chains; and (4) Digital technologies. The sustainability and innovation segment includes several of the topics noted above, and the Deloitte report elaborates, saying that "the majority of the challenges with ESG (environmental, social and governance) implementation are associated with a lack of low-carbon alternatives or the cost of abatement." (For more on ESG, see pp. 35–39.)

And while the ACC reports that supply-chain bottlenecks have been easing, they are still a major concern and the industry is evaluating supply-chain structures. The Deloitte report notes that one response has been to create local feedstock systems through bio-based and recycled materials that are also sustainable. Digital-technology is also being applied to help alleviate challenges, such as those associated with supply-chain management.

There are many exciting developments taking place in the CPI and we look forward to covering them as they unfold. Our best wishes to all for a happy and healthy new year.

Dorothy Lozowski, Editorial Director

1. ACC, Year-End 2022 Chemical Industry Situation and Outlook, December 2022.



A step closer to bio-based secondary diols in polyester synthesis

Isosorbide is a glucose-derived, rigid, secondary diol monomer that can impart favorable mechanical, barrier and thermal properties to condensation polymers, such as polyesters. However, for the past two decades, it has not been possible to synthesize fully bio-based poly(isosorbide succinate) (PlsSu), for example, due to the low reactivity of isosorbide in transesterifications. It was also nearly impossible to arrive at sufficiently long polymer chains (to achieve a certain ductility) while incorporating sufficiently high amounts of isosorbide (to arrive at a strong and durable material).

Now, researchers at the Industrial Sustainable Chemistry group of the University of Amsterdam (the Netherlands; www.uva.nl), led by professor Gert-Jan Gruter, have devised a simple synthesis strategy to overcome the inherently low reactivity of bio-based secondary diols. As described in a recent issue of *Nature Communications*, the researchers overcame the poor reactivity of isosorbide by incorporating an aryl alcohol in the polymerization process. This led to *in situ* formation of reactive aryl esters and a significant enhancement of the end-group reactivity during polycondensation, the last stage of polyester synthesis when isosorbide's low reactivity inhibits chain growth in

traditional melt polyesterification. As a result, high-molecular-weight materials could be produced with incorporation of high fractions of the bio-based, rigid secondary diol, even up to 100 mol%. For the first time, high-molecular-weight PlsSu could be produced, the polyester obtained from isosorbide and succinic acid. The resulting strong plastics outperform existing plastics like polyethylene terephthalate (PET) in terms of heat resistance, and also show promising barrier and mechanical properties that can outperform common fossil-based materials.

The researchers foresee exploration of previously inaccessible polyester compositions based on monomers with a low reactivity but also the application of similar methods in other classes of polymers, such as polyamides and polycarbonates.

The research was carried out within the RIBIPOL project, funded by the Dutch Research Council NWO with contributions from industry, including The LEGO Group (Billund, Denmark) and Avantium Chemicals B.V. (Amsterdam). The toy company supported the project as part of the search for non-fossil alternatives for its plastic bricks, which are currently made of acrylonitrile butadiene styrene (ABS). Avantium is interested in bottle and film applications.

Ultralight fabric solar cells turn any surface into a power source

Developed by researchers at the Massachusetts Institute of Technology (MIT; Cambridge, Mass.; www.mit.edu), these durable, flexible solar cells are glued to a strong, lightweight fabric, making them easy to install on a fixed surface. They are one-hundredth the weight of conventional solar panels, generate 18 times more power-per-kilogram, and are made from semiconducting inks using printing processes that can be scaled in the future to large-area manufacturing.

Already six years ago, the research team from the Organic and Nanostructured Electronics Laboratory (ONE Lab) produced solar cells using an emerging class of thin-film materials that were so lightweight they could sit on top of a soap bubble. But these ultrathin solar cells were fabricated using complex, vacuum-based processes, which can be expensive and challenging to scale up. In this work, described in *Small Methods*, the thin-film solar cells are instead entirely printable.

To produce the solar cells, the researchers coat the solar cell structure using a slot-die coater, which deposits layers of the electronic materials onto a prepared, releasable substrate that is only 3- μ m thick. Using screen printing, an electrode is deposited on the structure to complete the solar module. The researchers can then peel the printed module, which is about 15- μ m thick, off the plastic substrate, forming an ultralight solar device. To prevent the fragile device from tearing, the module is glued to a composite fabric (Dyneema) that weighs only 13 g/m².

While their solar cells are far lighter and much more flexible than traditional cells, they would need to be encased in another material to protect them from the environment. Work is underway to develop ultrathin packaging solutions.

The research is funded, in part, by Eni S.p.A. through the MIT Energy Initiative, the U.S. National Science Foundation, and the Natural Sciences and Engineering Research Council of Canada.

Edited by:
Gerald Ondrey

BTX EXTRACTION

A newly launched series of blended solvents for the extraction of benzene, toluene and xylenes (BTX) from a variety of feeds shows improved performance over single solvents, while avoiding environmentally problematic solvent components. The series, known as BTX Gold, was launched by GTC Vorro Technology (Houston; www.gtcvorro.com) in November.

"Our work on solvent extraction has shown that BTX Gold generates better performance in aromatics extraction, in terms of selectivity, solvency, and mass transfer than single-component solvents," says GTC Vorro director of technology Joe Gentry. With the series of proprietary blends, GTC Vorro Technology focused on ensuring that all components meet the requirements of environmental regulations, such as REACH in Europe and TSCA in the U.S.

BTX Gold has several variations, depending on the application for which it is used. For example, one blend of the series is designed for de-aromatization of naphtha from steam-cracker feed using liquid-liquid extraction (LLE). Other blends are designed for removing BTX from pyrolysis gasoline, FCC gasoline, or coke-oven light oil. In addition to LLE, the BTX Gold solvents can also be used in extractive distillation applications.

WOOD POWER

A small amount of electricity (bioelectricity) is generated in plants during transpiration — the movement of water through the plants and subsequent evaporation.

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This hydrovoltaic effect occurs at the interface of water and polarizable materials, due to the presence of an electric double layer at the solid-liquid interface.

In an effort to capitalize on this phenomenon, scientists at KTH Royal Institute of Technology (Stockholm, Sweden; www.kth.se) have refined wood samples to increase the amount of bioelectricity sufficiently to be “harvested” into useful power. As described in a recent issue of *Advanced Functional Materials*, the scientists used a one-step chemical process to nano-engineer the wood. This was done by immersing wood into an aqueous sodium hydroxide solution for several days at -6°C . The treated wood was shown to have a microporous structure with nanoporous cellulosic networks within the lumen.

“We have compared the porous structure in regular wood with the material we have improved with regard to surface, porosity, surface charge and water transportation. We have measured electricity generation that’s ten times higher than natural wood,” says Yuanyuan Li, associate professor at the KTH Division of Biocomposites. She adds that further tuning the pH difference between wood and water, due to an ion concentration gradient, achieves a potential of up to 1 V and a power output of $1.35\ \mu\text{W}/\text{cm}^2$ — enough to run an LED or calculator. To power a laptop computer would require about $1\ \text{m}^2$ of wood (1-cm^2 thick) and about 2 L of water, she says.

TOUGH ALLOY

Scientists have measured the highest toughness ever recorded — of any material — while investigating a metallic alloy made of chromium, cobalt and nickel (Cr-CoNi). Not only is the metal extremely ductile (highly malleable) and strong (resists permanent deformation), its strength and ductil-

Hydrogen-enabled recovery of raw materials from ‘red mud’ and other metallurgical waste

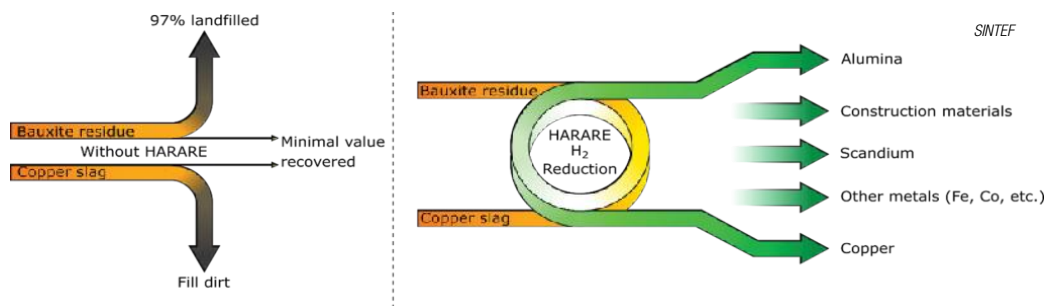
Bauxite residue (red mud) is a by-product from the smelting of aluminum. Like other waste slags from the metallurgy industry, bauxite residue is traditionally put into hazardous-waste landfills, although it contains a mixture of valuable raw materials in low concentrations. A new process is being developed in a four-year, European project, called HARARE (Hydrogen As the Reducing Agent in the REcovery of metals and minerals from metallurgical waste), which began in June 2021.

Led by Sintef (Trondheim, Norway; www.sintef.no), with nine industry and research partners from four European countries, the four-year HARARE project aims to recover copper and aluminum, as well as iron, cobalt, scandium and other critical metals from copper slag and bauxite residue (diagram), without generating CO_2 emissions in doing so.

Conventional aluminum smelting processes generate about twice as much

red mud as Al metal, and copper smelting generates about 2.2 metric tons of slag for every kilogram of Cu metal produced. Although metallurgical slags contain mineral and metal residues, these have only low concentrations of the metals and minerals of interest, which makes them difficult to recover economically. For example, slag that contains less than 1% copper will normally be regarded as waste and dumped. Other rare and valuable metals and minerals occur in even smaller concentrations.

Iron oxide is the main component in both the slag from flash smelting of copper and the bauxite residue from alumina production in the Bayer process. In the Harare concept, the iron oxide is reduced with hydrogen (instead of carbon) at high temperatures, thus avoiding the release of CO_2 . Once the iron is recovered, the copper, alumina and other metals can be recovered by metallurgical treatment. After metals are recovered, the remaining residue could be suitable for building materials.



Solvent-based regeneration of granular activated carbon

Granular activated carbon (GAC) can be used to remove polyfluoroalkyl substances (PFAS) from groundwater and drinking water, but current methods to regenerate spent GAC are costly and require high temperatures of greater than $1,000^{\circ}\text{C}$. A team of scientists at Battelle Memorial Institute (Columbus, Ohio; www.battelle.org) has developed a solvent-based method for restoring PFAS-laden GAC that requires much less energy and time than the conventional method.

The Battelle researchers identified two organic-alcohol solvents that were effective for the GAC regeneration process and developed a product, known as GAC Renew, based on those solvents. To regenerate the GAC at a water-treatment facility, one treatment tank is taken offline while a second tank allows GAC treatment to con-

tinue. The regenerant solution is stored on site and is cycled through the tank for the number of bed volumes that best regenerate the GAC, according to Battelle. The number of bed volumes is determined during laboratory column studies. After the solution has regenerated the spent GAC, potable water is passed through that tank to rinse the GAC before putting it back online, Battelle explains.

The GAC Renew process can reactivate GAC at lower cost than heating the GAC, and the PFAS-removal performance of the solvent-regenerated GAC is better than virgin GAC, even after four solvent-regeneration cycles, Battelle says.

The spent regeneration solution can be distilled for recycling and the concentrated distillate treated on site with Battelle’s PFAS Annihilator Destruction Technology (see *Chem. Eng.*, March 2022, p. 8).

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Wireless device detects coronavirus — no batteries required

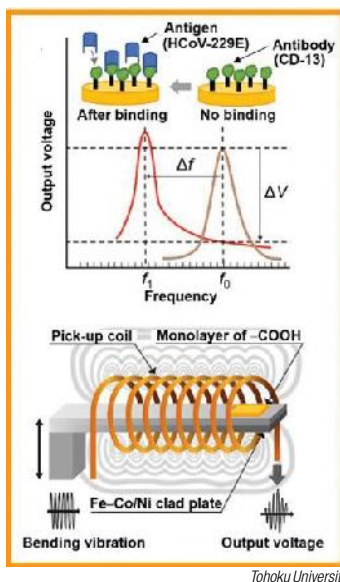
A collaborative research group in Japan has engineered a self-sustaining device that can detect the presence of COVID-19 particles or droplets in air. The device, which requires no batteries, employs a magnetostrictive clad plate composed of iron, cobalt and nickel, generating power via alternative magnetization caused by vibration. The vibration resonance frequency of the Fe-Co/Ni plates, which are coated with the receptor protein coronaviruses use to enter our cells, changes when the virus is absorbed, providing an indication that COVID-19 particles are in the air.

“We know that resonance frequency changes when the weight of a magnetostrictive material changes, but we set out to answer whether this is also the case when a virus is absorbed and if this absorption is detectable,” says Fumio Narita, co-author of the study — published in *Sensors and Actuators A: Physical* — and professor at Tohoku University’s (Sendai, Miyagi, Japan; www.tohoku.ac.jp) Graduate School of Environmental Studies.

The researchers modified a 0.2-mm thick Fe-Co/Ni

plate with a rectifier/storage circuit that harvests bending vibration energy and enables the wireless transmission of information. The plate transmits signals with the power obtained from bending vibration at 115 or 116 Hz. A change in clad plate weight affected the resonance frequency and altered the transmission intervals, meaning it could detect any substances that adhered to the clad plate. Next, the group created the bio-recognition layer, choosing to focus on human coronavirus 229E (HCoV-229E) — one of the seven types of coronavirus that affects humans. They immersed the clad plate in a CD13 protein solution and performed sensing experiments. When the coated clad plate was subjected to bending vibration, the resonance frequency decreased after HCoV-229 was absorbed, verifying whether the charged power could transmit virus detection as a signal.

The device could be used on other pathogens with modifications to the bio-recognition layer. “In the future, we hope to further develop our device and see if it applies to other viruses, such as MERS, SARS and COVID-19,” says Narita.

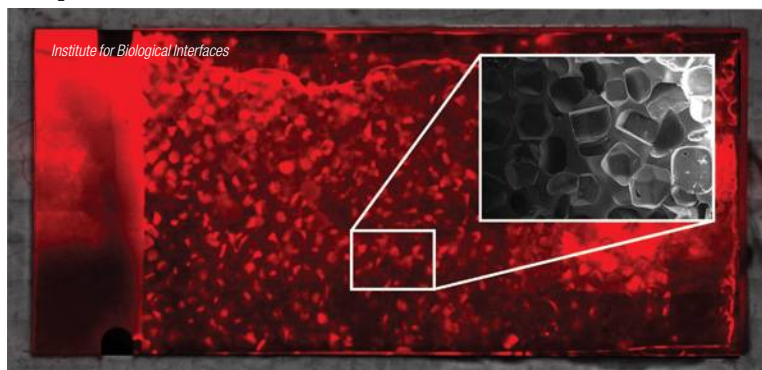


Tohoku University

A new tool to capture ‘microbial dark matter’

Microorganisms populate nearly any habitat, no matter how hostile it is. Their great variety of survival strategies is of huge potential in biotechnology. However, most of these organisms are unknown, because they cannot be cultivated. To make better use of this “microbial dark matter” (MDM), a team of researchers from Karlsruhe Institute of Technology (KIT; Germany; www.kit.edu) has developed a “sponge” made of porous, formable silicone. Embedded in a chip, the material sucks up microorganisms in the surroundings, which can then be applied for further research.

“It is quite surprising that nobody ever thought of using medical silicone for the settlement of bacteria,” says Christof Niemeyer, professor for Chemical Biology at KIT’s Institute for Biological Interfaces-1. The special polymer — used for breast implants, for example — does not interact with its environment. It can be modified easily, is long-lived and inexpensive. “The material can take up microorganisms from the environment, no matter how moist or dry it is. For this purpose, the silicone had to be processed to a porous, sponge-like structure,” he explains. The porosity was introduced into the polymer by adding sodium chloride, which was



then dissolved, resulting in the sponge-like material. Modified and unmodified silicone were then combined to form “chips” (photo), as described in a recent issue of *Applied Materials & Interfaces*.

Experiments revealed that this silicone sponge captures

a very large range of microorganisms in its pores. In the dry air of a poultry farm, the team identified Actinobacteriota species. These microorganisms are needed for the production of antibiotics. Moreover, they can be applied to produce substances to treat certain cancer diseases. “With the sponge, we can catch new bacteria that might benefit biomedicine,” Niemeyer believes.

When the silicone sponge was immersed into a pool to cultivate pikeperch, researchers found many bacteria belonging to the Candidate Phyla Radiation group — far more than in conventional, commercially available material. “These microorganisms account for about 70% of the microbial dark matter, as they have not been cultivable so far,” says professor Anne-Kristin Kaster from the KIT Institute for Biological Interfaces-5. She and her team analyzed the captured microorganisms using the latest sequencing technology.

A patent application has been filed for the silicone chip.

New pressure-relief valves improve performance and reduce emissions

Spring-loaded pressure-relief valves (PRVs) often use bellows to ensure balanced operation. Data analysis from 30,000 PRV service records across different industries and valve brands shows a bellows failure rate between 2 to 6%, according to Emerson (St. Louis, Mo.; www.emerson.com). The most common causes of bellows failures are excessive backpressure and rapid cycling. Ruptured bellows will cause fugitive emissions and may prevent valve operation at the designed set pressure, with the risk of catastrophic overpressure events.

To address these issues, Emerson introduced two new technologies for its Crosby J-Series PRV line. The first is a Balanced Diaphragm, which eliminates the need for bellows in PRVs, while providing balanced operation

against backpressure. Its design extends the backpressure limits from 60% to 80%, and increases the backpressure correction factor, K_b , by up to 15%, expanding the application range of spring-loaded PRVs. Extending the backpressure limit and increasing the K_b factor often permits the use of smaller valves, the company says.

The second technology is Bellows Leak Detection, enabling remote detection of bellows ruptures in PRVs, with the capability to reduce and accurately calculate volumetric emissions in real time. It consists of a backup piston and a Rosemount wireless or wired pressure transmitter. The backup piston can reduce emissions by over 90% in the event of a bellows rupture because it has a much smaller clearance than a standard bonnet vent, and it ensures balanced operation.

ity improve as it gets colder — contrary to most other materials in existence.

The team, led by researchers from Lawrence Berkeley National Laboratory (Berkeley Lab; Calif.; www.lbl.gov) and Oak Ridge National Laboratory (Tenn.; www.ornl.gov), published a study describing their record-breaking findings in *Science* last month.

CrCoNi is a subset of a class of metals called high-entropy alloys (HEAs). All the alloys in use today contain a high proportion of one element with lower amounts of additional elements added, but HEAs are made of an equal mix of each constituent element. These balanced atomic recipes appear to bestow some of these materials with an extraordinarily high combination of strength and ductility when stressed, which together make up what is termed “toughness.”

The toughness of this material near liquid helium temperatures (20K; -424°F) is as high as 500 MPa·m^{1/2}, which is about five times higher than some of the best steels.

ADSORBING NITRATES

Nitrate ions released into water bodies due to human activities can have adverse effects on aquatic and terrestrial ecosystems. Conventional adsorption materials that are used for treating water contamination are incapable of removing nitrate. To deal with this issue, researchers from Chiba University (Japan; www.chiba-u.ac.jp) have developed functionalized carbon fibers that exhibit excellent nitrate adsorption properties, as reported in a recent issue of *SN Applied Sciences*.

“Carbonaceous materials like activated carbons are usu-

(Continues on p. 10)

ally functionalized with negatively charged functional groups, such as carboxy, carbonyl or phenol, which show excellent adsorption performance for positively charged ions and organic pollutants but are ineffective against inorganic negatively charged ions,” explains professor Motoi Machida. “So, we wanted to develop a durable activated carbon fiber (ACF)-based material that can efficiently adsorb nitrate ions and retain adsorption capacity for multiple uses.”

In the study, polyacrylonitrile (PAN)-based carbon fibers with high (20%) nitrogen content were activated at 800°C with sodium carbonate to increase the surface area, then heat treated (annealed) at 950°C, which reduced the nitrogen content, but increased the amount of quaternary nitrogen — a positively charged functional group capable of nitrate adsorption.

Tests with the material showed that heat treatment increased the nitrate adsorption capacity by eliminating nitrate-repelling functional groups, such as $-\text{COOH}$ and $-\text{COO}-$. The PAN-ACF material showed an adsorption capacity of 0.5 mmol/g nitrate ions from water. “Our new robust material can withstand treatments with boiling water, and strong acidic and basic solutions, and thereby can still easily regenerate with minimal loss in adsorption capacity,” says Machida. 

Converting waste paper into better battery anodes

Scientists from Nanyang Technological University, Singapore (NTU Singapore; www.ntu.edu.sg) have developed a technique to convert waste paper, from single-use packaging, bags and cardboard boxes, into electrodes, which can be made into rechargeable batteries that power mobile phones, medical equipment and electric vehicles. To carbonize the paper, the team exposed the paper to high temperatures, which reduced it to pure carbon, water vapor and oils that can be used for biofuel. Because the carbonization takes place in the absence of oxygen, the process emits negligible amounts of carbon dioxide, so the process is a “greener” alternative to disposing of waste kraft paper by incineration.

To produce the carbon anodes, the NTU researchers joined and laser cut several thin sheets of kraft paper to form different lattice geometries. The paper was then heated to 1,200°C

in a furnace without the presence of O_2 , to convert it into carbon, forming the anodes. Anodes produced by the research team also demonstrated superior durability, flexibility and electrochemical properties. As reported in a recent issue of *Additive Manufacturing*, laboratory tests showed that the anodes could be charged and discharged up to 1,200 times, which is at least twice as durable as anodes in current phone batteries. Batteries with these anodes could also withstand more physical stress than their counterparts, absorbing crushing energy up to five times better. The researchers attribute the anode’s superior durability, flexibility and electrochemical properties to the arrangement of the paper fibers.

The research team has filed for a patent with NTUitive, NTU’s innovation and enterprise company. They are also working towards commercializing their technology. 

LINEUP

AIR LIQUIDE
AIR PRODUCTS
ARCELORMITTAL
CEPSA
COVESTRO
CROPENERGIES
EXXONMOBIL
HONEYWELL
INEOS
INVISTA
JOHNSON MATTHEY
NOURYON
OCI
RÖHM
SHELL
SYNTHOMER

Plant Watch

Air Liquide to supply H₂ and CO to Kumho Mitsui Chemical

December 13, 2022 — Air Liquide S.A. (Paris, France; www.airliquide.com) has signed a long-term contract to supply Kumho Mitsui Chemical (KMCI) with additional hydrogen and carbon monoxide in South Korea's Yeosu National Industrial Complex, where Air Liquide currently operates four production units. This contract will enable Air Liquide to support KMCI's additional expansion of 200,000 metric tons per year (m.t./yr) of methyl diphenyl diisocyanate (MDI).

CropEnergies to build renewable ethyl acetate plant in Germany

December 13, 2022 — CropEnergies AG (Mannheim, Germany; www.cropenergies.com) plans to build a plant for the production of renewable ethyl acetate from sustainable ethanol. The planned location for the plant is the Zeitz Chemical and Industrial Park, in Elsteraue, Germany. The total investment for the new production facility will be around €120–130 million. Groundbreaking is to take place early in 2024 and the commissioning is scheduled for summer 2025.

OCI breaks ground on major ammonia facility in Texas

December 9, 2022 — OCI N.V. (Amsterdam, the Netherlands; www.oci.nv) started construction on a 'blue' ammonia facility in Texas, which is scheduled to begin operation in 2025. The project's site is adjacent to OCI's existing integrated 1.4-million-m.t./yr methanol-ammonia production facility in Beaumont and 1.8-million-m.t./yr 50%-owned methanol joint venture, Natgasoline.

Air Products and AES to build first mega-scale 'green' hydrogen facility in Texas

December 9, 2022 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) and The AES Corp. (Arlington, Va.; www.aes.com) plan to invest approximately \$4 billion to build, own and operate a 'green' hydrogen production facility in Wilbarger County, Tex. This renewable-power-to-hydrogen project includes approximately 1.4 GW of wind and solar power generation, along with electrolyzer capacity capable of producing over 200 m.t./d of hydrogen, making it the largest 'green' hydrogen facility in the U.S.

Johnson Matthey expands formaldehyde plant in Sweden

December 6, 2022 — Johnson Matthey plc (London; www.matthey.com) announced the expansion of its manufacturing facility in Perstorp, Sweden, to meet growing

demand for formaldehyde. The expansion, which will be operational by the end of March 2024, will increase the site's capacity by approximately 50%.

ExxonMobil doubles polypropylene production at Baton Rouge

December 6, 2022 — ExxonMobil Corp. (Houston; www.exxonmobil.com) announced the startup of its new polypropylene production unit at its polyolefins plant in Baton Rouge, La. The unit increases polypropylene production capacity along the Gulf Coast by 450,000 m.t./yr. The total capital investment was more than \$500 million.

Cepsa to invest €3 billion to build the largest 'green' hydrogen hub in Europe

December 2, 2022 — Cepsa (Madrid, Spain; www.cepsa.com) will invest more than €3 billion to establish the Andalusian Green Hydrogen Valley, creating the largest 'green' hydrogen hub in Europe in southern Spain. Cepsa will build two plants with a total capacity of 2 GW to produce 'green' hydrogen. The plants, each with 1 GW of capacity, will be located in Palos de la Frontera (Huelva) next to Cepsa's La Rábida Energy Park and at the company's San Roque Energy Park in Cádiz. The Huelva plant will start up in 2026, reaching full capacity in 2028, while the Cádiz facility will be operational in 2027.

Honeywell doubles production capacity for Solstice ze in Baton Rouge

December 1, 2022 — Honeywell International Inc. (Charlotte, N.C.; www.honeywell.com) announced that its Baton Rouge facility has doubled production capacity for Solstice ze (HFO-1234ze). Solstice ze is used in foam insulation, as an aerosol propellant and in refrigeration and air-conditioning applications.

Covestro starts up NDI plant in Thailand

November 28, 2022 — Covestro AG (Leverkusen, Germany; www.covestro.com) started up production of naphthylene-diisocyanate (NDI) at a newly built plant at its Map Ta Phut site in Thailand. The plant is part of several recent investments by the company into cast polyurethane raw materials.

Invista inaugurates adiponitrile plant at Shanghai Chemical Industry Park

November 28, 2022 — Invista (Wichita, Kan.; www.invista.com) inaugurated its new adiponitrile plant at the Shanghai Chemical Industry Park. The plant is a critical part of Invista's integrated nylon 6,6 value chain, and represented an investment of over \$1 billion. It has a capacity of 400,000 m.t./yr of adiponitrile.



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Mergers & Acquisitions

Synthomer divests laminates, films and coated fabrics assets

December 13, 2022 — Synthomer Plc (London, U.K.; www.synthomer.com) intends to sell its laminates, films and coated fabrics businesses to Surteco Group for \$255 million (£208 million). Surteco is a Germany-based developer, designer, producer and marketer of surface materials based on paper and plastics. The laminates, films and coated fabrics businesses were acquired as part of the purchase of Omnova Solutions Inc. in 2020.

Röhm agrees to acquire Sabic's Functional Forms business

December 8, 2022 — Röhm GmbH (Darmstadt, Germany; www.roehm.com) has agreed to acquire the Functional Forms business of Sabic (Riyadh, Saudi Arabia; www.sabic.com). With this acquisition, Röhm adds polycarbonate sheets and films to its existing range of polymethyl methacrylate (PMMA) sheets and films. The new combined business will have sales of more than €700 million.

Ineos takes 50% stake in Sinopec ethane cracker in Tianjin

December 7, 2022 — Ineos Ltd. (London; www.ineos.com) and Sinopec Group (Beijing, China; www.sinopecgroup.com) have announced a new joint venture agreement under which Ineos acquires a 50% share in the existing Tianjin Nangang Ethylene Project from Sinopec. The project is currently building a 1.2-million-m.t./yr ethane cracker, expected to come onstream at the end of 2023, and several other downstream derivative plants in Tianjin, China.

ArcelorMittal acquires scrap-metal recycling business

December 6, 2022 — ArcelorMittal S.A. (Luxembourg; www.arcelormittal.com) announced that it has acquired Riwald Recycling, a ferrous scrap-metal recycling business based in the Netherlands. Riwald Recycling operates two fully certified scrap-metal yards in Almelo and Beverwijk, the Netherlands, both of which have direct port access. Riwald processed over 330,000 m.t. of ferrous scrap metal in 2021. It sources

material from industrial companies, demolition companies, traders, car dismantling companies and regional and national governments.

Nouryon purchases alkoxylation plant in Singapore

December 6, 2022 — Nouryon N.V. (Amsterdam, the Netherlands; www.nouryon.com) acquired an alkoxylation plant on Jurong Island, Singapore to enhance the company's ability to serve key end markets, including agriculture, food, home and personal care, natural resources and paints and coatings.

Shell acquires biogas firm in Denmark

December 1, 2022 — Shell plc (London; www.shell.com) agreed to acquire Nature Energy Biogas A/S for \$2 billion. Based in Denmark, Nature Energy is a producer of renewable natural gas from agricultural, industrial and household wastes. The acquired firm currently has 14 operating sites and a pipeline of around 30 new plant projects in Europe and North America. ■

Mary Page Bailey

Doing Multiple Experiments at the Same Time

New equipment and systems for high-throughput and parallel experiments are speeding the development of catalysts and optimizing processes for both traditional and emerging industries

High-throughput screening has been used for many years in the pharmaceutical industry, especially for drug discovery. More recently, systems are being developed for catalyst testing and process optimization in many sectors of the chemical process industries (CPI). The following is a brief look at the some of these new developments.

Catalyst testing

Integrated Lab Solutions GmbH (ILS; Berlin, Germany; www.integrated-labsolutions.com) develops systems enabling many catalysts and processes to be tested simultaneously. "By performing experiments in parallel, the development time is radically reduced and data quality is improved," says Anton Nagy, CEO and founder of ILS. "Miniaturization and automation make significant reductions in operating costs possible by reducing manpower and infrastructure required for catalyst testing."

ILS offers a number of different high-throughput tools for testing as

many catalysts in as short a period of time as possible, including 16-, 32- and 48-parallel, fixed-bed reactors and 10- to 96-parallel batch reactors. Some examples of recent units include the following:

- For the group of professor Guy Marin at the University of Ghent, a 16-parallel trickle-flow reactor for both gas-phase reactions at temperatures up to 700°C and low-temperature trickle-flow reactions at pressures up to 100 bars
- For Sasol, a 32-parallel Fischer-Tropsch testing unit for catalyst screening and aging
- For Evonik Industries AG, a multipurpose 16-parallel ultra-high pressure (up to 300 bars) trickle-flow unit
- For Syngenta, a 20-parallel asymmetric hydrogenation/carbonylation reactor for screening of air and moisture-sensitive homogeneous and heterogeneous catalysts in a corrosive environment

There have been a number of new advancements that have been extremely valuable, Nagy says. "At ILS, we have developed a unique Temkin modular-reactor approach that makes it possible for catalyst testing on full-scale particles to be performed at extremely small scales (Figure 1). This is particularly valuable for eggshell-type catalysts used for fast, strongly exothermic reactions like vinyl acetate monomer (VMA) synthesis or for C2 and C3 selective hydrogenation," Nagy explains. The ILS Temkin modules are extremely compact and flexible and hydrodynamically optimized to provide true plug flow without having

to add inert filler without wall-effects. "A six-parallel reactor for example is a fraction of the size of a five-parallel reactor done in more traditional, large-diameter tubes. This requires far less feedstock and related safety infrastructure saving clients time and money," he says.

The ILS low-pressure, high-speed Berty reactor (Figure 2) is a unique development that was developed in close collaboration with the Friedrich Alexander University of Erlangen, Nagy continues. "Traditional Berty reactors only provide sufficient internal recycle to be truly concentration- and temperature-gradient free at pressures above about 10 barg. Current interest is particularly in reactions like steam-methane reforming (SMR) and dry reforming that require low pressures, where traditional Berty-type internal recycle reactors fail, he says. ILS can provide this unique tool capable of performing kinetic studies on powders or pellets at low to high pressures (up to 800°C). "These tools are currently being used to help petroleum refiners develop improved catalyst particle geometries, with reduced pressure drop and improved mass-transfer behavior for key reactions like SMR, where CO₂ reduction is key to reducing greenhouse gas emissions," Nagy says.

More sustainable processes

"High-throughput reaction testing, particularly for difficult applications, such as biomass upgrading or plastics pyrolysis, requires novel approaches to reactor design, Nagy continues. Recently, a High-Throughput Biomass Upgrading unit was developed in close collaboration with the National Renewable Energy



FIGURE 1. First conceived in the 1960s, this modern version of the Temkin reactor enables catalyst testing on full-scale particles

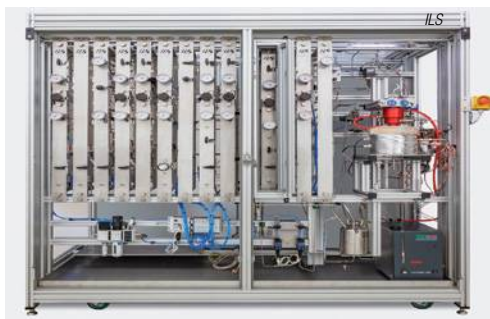


FIGURE 2. The Berty reactor can be used to optimize low-pressure steam-methane reforming and dry reforming



FIGURE 3. To address the challenges of the chlorine industry, hte recently developed a high-throughput, laboratory-scale technology that is able to test 16 catalysts in parallel under industrially relevant conditions

Laboratory (NREL; Golden, Colo.; www.nrel.gov). The system (Figure 2) provides a powerful tool for studying how to convert lignocellulose to fuels or chemicals.

“Fluidized-bed testing at small scale is extremely challenging as scaling down the hydrodynamics of large reactors and simultaneously producing scalable results is virtually impossible,” says Nagy. “Given the increased significance of FCC (fluid catalytic cracking) conversion of green(er) feedstocks derived from plastic or biomass-derived sources, as well as the use of fluidized-bed technologies for chemical looping or CO₂-adsorption-enhanced conversions means that tool development in this area is particularly important, he says. “I see real possibilities for new, high-throughput technology development in these areas.”

At hte GmbH — the high throughput experimentation company (Heidelberg, Germany; www.hte-company.com), there have been a number of recent projects for both traditional industrial processes, as well as for emerging ones related to sustainability. For example, to address the challenges of the chlorine chemistry, the company recently developed a high-throughput, laboratory-scale technology that is able to test 16 catalysts in parallel under industri-

ally relevant conditions (Figure 3). The system is designed to accelerate the assessment of catalyst activity, selectivity and decay. It can process corrosive gases at high HCl intake and extended runtime that also includes offgas treatment on a kilogram scale.

Since October 2021, hte has been working with Hanwha Solutions Corp. (Seoul, South Korea; www.hanwhasolutions.com) to test Hanwha’s catalysts to construct a sustainable catalytic process in the chlor-alkali value chain.

More recently (last September), hte was awarded a contract by the Research Center Jülich (Germany; www.fz-juelich.de) for a high-throughput test system for testing electrolysis. “We are pleased to extend our core competence in catalyst testing into the emerging field of electrocatalysis and hydrogen generation, comments Wolfram Stichert, CEO at hte.

In another sustainability-related project, hte supplied a four-fold precipitation unit for a flagship project — Cathode Precursor Production Pilot Plant — funded by the Future Battery Industries Cooperative Research Center (FBICRC; www.fbicrc.com.au). The project is being led by Curtin University’s Western Australian School of Mines: Minerals, Energy and Chemical Engineering (Perth, Australia; www.curtin.edu.au) and involves 19 industry, research and government participants. Officially opened in July, 2022, the pilot plant will run test campaigns for 18 months.

The hte unit (Figure 4) consists of four individual precipitation reactor systems that can be operated either in continuous or batch mode utilizing solid/liquid separators. The reactors can accommodate operating temperatures from 20 to 70°C under ambient pressure. The system is fully automated and

supported by hte’s proprietary software solution, hteControl, to allow for safe and unattended continuous operation.

Crystallization

Forming crystals with the right size, shape and other properties depends on a large number of parameters that must be optimized. Because this requires a lot of experiments, considerable time can be saved if more than one experiment can be performed at the same time. Since 2005, Technobis Crystallization Systems (Alkmaar, the Netherlands; www.crystallizationsystems.com) has provided platforms for accelerating crystallization research, which have been developed and installed in “nearly every pharmaceutical research laboratory in the world,” the company says. With eight independently controlled reactors and additional analytical capabilities, the company’s Crystalline is a unique modular product line at a working volume of 2.5 to 5 mL for solid-state research, process development and formulation research.

“The chemistry gets more and more complicated with the time; the compounds get more and more difficult. Therefore, much more attention needs to be paid on the solid state form or modify the form to be able to achieve the desired physico-chem properties,” says Carmen Guguta, Global Head of Business Development and Marketing at Technobis Crystallization Systems. “And there comes the need for instrumentation, reactor systems that allows companies to reliably make their desired forms.”

“Besides the multiple-reactors



FIGURE 4. This system has four individual precipitation reactor systems that can be operated either in continuous or batch mode for developing cathode precursors

systems, Technobis Crystallization Systems has recently brought to the market a software package based on artificial intelligence (AI). Nowadays, there are a lot of data available and therefore AI is more reliable and speeds up the drug-discovery and development of new APIs [active pharmaceutical ingredients],” says Guguta. “AI-based software is used to ease data analysis and facilitate taking the right decision as soon as possible during development,” she says.

Last November, the company launched the Crystalline Version 2, an eight-reactor parallel crystallizer for formulation and particle visualization. “The resolution of the cameras allows the user to analyze particles as small as close to nanometer scale,” explains Guguta. “The image analysis is based on AI software allowing the user to better understand particle properties and optimize their processes as early as possible. Raman spectroscopy is also an option on the Crystalline instrument, enabling chemists to follow chemical reactions of solid-form transformations while they are performing the experiments. If we are looking at macromolecules, Raman spectroscopy can be performed in-situ with the Crystalline instrument. For example, folding and unfolding of proteins can be easily detected,” she says.

Back in April, the company launched the Crystal16 V3 (Figure 5) — a multi-reactor crystallizer for medium throughput solubility. The latest version has integrated transmissivity technology and enhanced analytical capabilities, in a streamlined unibody design, to reduce the time and resources consumed in crystallization experiments and analysis. “Scientists can improve and accelerate their crystallization research with the Crystal16 parallel crystallizer, the ultimate instrument for research and process development. With 16 reactors at a volume of 1 mL, users can easily determine temperature-dependent solubility curves and screen for crystallization conditions,” says Guguta.

Other operations

Electrosynthesis. Pioneered by professor Sigfried Waldvogel, at the Johannes Gutenberg Univer-

sity of Mainz (JGU; Germany; www.uni-mainz.de), electrosynthesis can be achieved using a simple undivided cell (*Chem. Eng.*, September 2021, pp. 12–16). Because there are many parameters that need to be determined in developing such a process (such as electrode material, electrolyte, voltage, current and so on), Waldvogel developed a screening system for conducting multiple experiments at the same time. When combined with design-of-experiments (DoE) and machine learning (ML), the number of experiments needed to determine process conditions is greatly reduced, he says.

The screening system has since been further developed and commercialized by IKA-Werke GmbH & Co. KG (IKA; Staufen, Germany; www.ika.com), which offers two variations: one with six divided cells and another with eight undivided cells. The system includes the power and heating supplies, as well as the control system used for parallel processing of multi-batch electrochemical reactions. A large number of different electrode materials are also available.

Calorimetry. At Achema 2022 last August, the Fraunhofer Institute for Chemical Technology (ICT; Pfaffzettel, Germany; www.ict.fraunhofer.de) introduced its continuously operating reaction calorimeters, based on microreactors, which permits rapid screening of important thermo-kinetic data. The calorimeter has an array of sensors, based on Seebeck elements, for the localized, quantitative characterization of heat flows. The sensor arrays have up to 40 individual sensors, which can gather data on the heat generated in a microreactor with a high degree of temporal and spatial resolution. Because the rate of heat released is directly proportional to the reaction rate, basic kinetic and thermodynamic data of chemical reactions can be measured, ICT says.

Photochemistry. For developing photochemical reactions, Asynt Ltd. (Isleham, Ely, U.K.; www.asynt.com) offers its LightSyn Illumin8 parallel photochemistry reaction station for performing parallel chemistry screening. The unit sits on top of a hot plate for stirring and heating, and has eight



FIGURE 5. The Crystal16 V3 parallel crystallizer has 16 reactors, enabling researchers to determine solubility curves and screening for crystallization processes

parallel reactors illuminated by eight, 10-W LEDs. Available lamps include those for ultraviolet (365 nm) and visible (450 nm and more) radiation.

The company also offers the fReactor PhotoFlow module, which was developed at the Institute of Process Research and Development at the University of Leeds (www.iprd.leeds.ac.uk) in conjunction with Asynt. This system combines both photochemistry and flow chemistry, and can be used for up to five parallel reactions.

Microwave. Using microwaves for heating has a number of advantages: they heat up the reaction mixture directly inside the reaction vial without heating the surroundings. Unlike conventional heating sources, microwave heating can be turned on and off instantly, giving you complete control of the heating. To obtain real-time information about the chemical composition of pressurized reactions, Anton Paar GmbH (Graz, Austria; www.anton-paar.com) offers the Movowave 400 R, a microwave reactor with in-situ Raman spectroscopy. The system can be used to optimize reaction conditions based on the influence of different reaction parameters, different reagents and for detecting the ideal end point of a reaction. The system operates at temperatures up to 300°C and pressures up to 30 bars.

For multiple experiments, the company also offers its Rotor 4X24MG5, which is designed for “hit-to-lead” generation (an iterative approach for screening molecules) and parallel optimization in microwave synthesis. The unit has 96 disposable glass vials arranged in silicon carbide blocks for reaction conditions up to 200°C and 20 bars.

Gerald Ondrey

Focus on Valves

A next-generation intelligent valve controller for any valve

Introduced at Valve World Expo and Conference 2022 (November 29–December 1; Düsseldorf, Germany), the Neles NDX 2.0 (photo) is a next-generation intelligent valve controller offering more sustainable valve-control performance for all process industries, valves and applications. With its modular design, Neles NDX 2.0 is easy to install, use and service. The Neles NDX 2.0 has universal performance: it is designed to work on top of any valve and actuator, regardless of the manufacturer or valve size. It also provides interoperability with the most common automation systems and is suitable for all operating environments. The Neles NDX 2.0 valve controller provides a sustainable solution for all process industries, valves and applications. The Neles NDX 2.0 offers significant savings in air consumption and, consequently, in energy efficiency. The pneumatic relay of the controller has been redesigned so that it consumes approximately 80 to 90% less air than conventional controllers, says the company. — *Valmet Oy, Espoo, Finland*
www.valmet.com

This rotary valve automatically prevents metal contamination

Developed to protect food, pharmaceutical and other ingredients from metal particulate-matter contamination, the new RotaSafe RS1 valve rotor (photo) monitors rotary-valve operation continuously, automatically detects contact between the rotor and housing and, in the event of detection, immediately shuts down power to the drive motor to stop the process. The rotary airlock safety system is triggered before the powders or other bulk materials can become contaminated by foreign matter and before the valve incurs any damage from metal-to-metal contact. The RotaSafe RS1 features new programming and amplification hardware for enhanced functionality and superior control over detection accuracy, security and other parameters. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickegroup.com

This actuator range now offers a part-turn option

The CK range of modular electric valve actuators has been extended to include a new part-turn variant, known as the CKQ (photo). The entire range has a modular design that provides flexibility and high degrees of configurability, enabling a fast order turnaround and quick delivery. CK actuators provide flow control in non-hazardous locations and are especially suited for diverse applications in the water and power industries. This new part-turn variant is especially well suited for harsh and demanding environments and has an operational temperature range of –30 to 70°C. The IP68 enclosure protection is maintained even when the actuator terminal housing is removed (by using a double-sealing system around both parts of the plug and socket connection). — *Rotork plc, Bath, U.K.*
www.rotork.com

These butterfly valves are approved for oxygen service

A special version of the R480 Victoria butterfly valve series (photo) is approved for use with O₂. In the design for handling O₂, all media wetted seal materials and auxiliary materials (lubricants and screw locking agents) from the Victoria butterfly valve series have been tested and approved by the German Federal Institute for Materials Research and Testing (BAM). The examination for BAM approval was based on the DIN EN 1797 and ISO 21010 standard. Approval is limited to the use of gaseous O₂ at a maximum operating temperature of 60°C and a pressure of 15 bars. — *GEMÜ Gebrüder Müller Apparatebau GmbH & Co. KG, Ingelfingen-Criesbach, Germany*
www.gemu-group.com

Reduce TCO, improve safety with this slab gate valve

This company has introduced an improved version of its Model M-303 slab gate valve (photo, p. 18). The advanced-design M-303 offers a number of features that will help users in the oil-and-gas sector to simplify installation and upgrades, improve



Valmet Oy



Gericke USA, Inc.



Rotork



GEMÜ



Celeros Flow Technology



Sisto Armaturen



Praher Plastics Austria



AUMA Riester

safety and minimize environmental impacts — reducing total cost of ownership (TCO). Manufactured and tested for API 6D, the improved M-303 is suitable for high-pressure-differential applications. Its floating slab gate uses the natural force of line pressure to obtain a reliable, dynamically tight downstream seal. Low-pressure sealing is accomplished with a single wave spring that energizes the seat, pushing it firmly against the gate. This reduction in seal requirements, coupled with high packing reliability, dramatically reduces the likelihood of fugitive emissions. The valve is available in line sizes 6 to 84 in., class 150–2,500 pressure rating and with a choice of manual, electric, hydraulic or cylinder actuators. — *Celeros Flow Technology, Charlotte, N.C.*

www.celerosft.com

A future-proof diaphragm valve for drinking water

Valves installed in drinking-water transport systems have to meet stringent demands, both in terms of design and materials employed. To satisfy these requirements, this company has launched its SISTO-16RGAMaXX diaphragm valve series, featuring threaded sockets, a stainless-steel body and a special drinking-water diaphragm. The body is made of EN 1.4409 stainless steel, a material that is particularly resistant to chlorinated water and suitable for drinking water. The body is designed without dead volume, thus preventing deposits in the valve. Nominal sizes range from Rp 1/2 to 3 in. The confined and supported diaphragm maximizes service life and is designed for a pressure of 16 bars. It is made of high-quality elastomer (EPDM/W270). The valves cover a temperature range from –10 to 90°C, which makes the series suitable for thermal disinfection. — *Sisto Armaturen S.A., Luxemburg, part of KSB SE & Co. KGaA*

www.ksb.com

Diaphragm valves with safety and performance features

Thanks to its torque limiter, the T7 diaphragm valve (photo) can no longer be over-tightened when closed, thus protecting the diaphragm. A limit stop prevents the valve against sticking, when it is opened for a long time. The valves have a characteristic red handle with a yellow shut-off sleeve.

This ergonomically shaped, non-slip handwheel allows easy, one-handed operation and the new housing shape allows water and other liquids to completely drain away. The valves now handle an increased nominal pressure to PN 12.5. The valves are available in three different materials: polyvinylchloride (PVC), polypropylene (PP) and polyvinylidene fluoride (PVDF). Diaphragms are available in polytetrafluoroethylene (PTFE) or ethylene propylene diene monomer (EPDM) rubber. — *Praher Plastics Austria GmbH, Schwertberg, Austria*
www.praher-plastics.com

New actuators for hazardous environments and H₂

This company has added an explosion-proof version to its Profox actuator series. The smart and small actuators are ATEX and IECEx certified for the highest gas group IIC T4, which includes hydrogen. Other approvals are in progress. Profox actuators provide reliable, high-performance valve automation for process applications of all kinds. Built-in intelligence makes Profox equally suited to open-close duty and modulating applications. Adjustable speed ensures fast and precise positioning. Operating costs are low, thanks to high mechanical efficiency and low standby consumption. Innovative diagnostics and Fieldbus and Industrial Ethernet interfaces ensure future-proof plant automation. The Profox platform, including multi-turn, part-turn and linear actuators, offers versatile valve actuation solutions for the lower torque ranges. The compact Profox actuators are suitable for limited spaces, such as skid installations. Profox actuators are simple and easy to use, with rapid installation and commissioning via an intuitive application. — *AUMA Riester GmbH & Co. KG, Muellheim, Germany*

www.profox.auma.com

Check valves in a variety of materials and sizes

This company has added the Adapter Valve (photo, p. 20) to its full-service line of spring-loaded piston-type check valves. The Adapter Valve is available in two styles, model AM (MNPT x FNPT) and model AF (FNPT x MNPT). Both models have the same size pipe thread on both ends for installation where a threaded straight adapter is needed. The one-piece



Check-All Valve



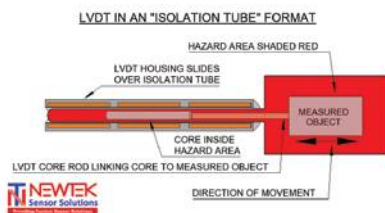
Ebro Armaturen Gebr. Bröer



Flowserve



Groth



New Tek Sensor Solutions

body design is machined from high-quality bar stock. The valves are available in sizes 1/2 to 4 in. (NPT threads). Body materials include 316 stainless steel, brass, carbon steel, Alloy 20, Alloy B, Alloy C-276, Monel 400 and titanium. Seat materials are available in AFLAS, Buna-N, EPDM, Kalrez, "Metal-to-Metal", Neoprene, PTFE and FKM. Springs are available in 316 stainless steel, Alloy C-276, Alloy B, Inconel X750, Monel 400, 17-7PH stainless steel and titanium. — *Check-All Valve Mfg. Co., Des Moines, Iowa*
www.checkall.com

Individual solution for discharging and dosing

The TS cycle lock (photo) is used whenever the discharge from silos, weighing containers, filter systems or big bags and the feeding into downstream production processes, such as vacuum reactors, screening machines, mixers or packaging systems, cannot be realized with standard valves. The TS cycle lock is available with nominal diameters from DN 50 to DN 1200. Its chamber volume, as well as the geometry of the filling pipe, can be customized. Installation is simple. As a rule, it is sufficient to connect the TS cycle lock to the vessel or the pipeline. Capacitive sensors or, for simpler media, vibrating-rod limit switches are available for monitoring the filling level. Furthermore, the opening of the inlet and outlet valve can also be time-controlled. TS cycle locks are gas-tight and ATEX-certified. They are therefore suitable as a safe solution for use as passive explosion decoupling systems with nominal diameter from DN 50 to DN 600 in plants with differential pressures of up to 10 bar. — *Ebro Armaturen Gebr. Bröer GmbH, Hagen, Germany*
www.ebro-armaturen.com

A butterfly valve designed for CSP power plants

The Valtek TX3 Molten Salt triple-offset butterfly valve (photo) was designed to provide concentrated solar power (CSP) plant operators with reliable performance, tight shut-off and minimized maintenance in molten-salt applications. Eliminating leakage in the demanding conditions required for thermal energy storage for industrial processes is a top priority. The design and construction of TX3 Molten Salt valve can withstand tem-

peratures ranging from 260 to 600°C with standard live-loaded hybrid or Thermiculite packing. It maintains the packing load for constant external sealing during thermal cycling. — *Flowserve Corp., Dallas, Tex.*
www.flowserve.com

New valves reduce product evaporation losses

The Model 12E (photo) and Model 12F weight-loaded pressure/vacuum relief valves (PVRV) are said to achieve both superior sealing performance and industry-leading flow-rates, while allowing users to reach the required flow with a potentially smaller-sized valve. The Model 12E and 12F weight-loaded PVRVs feature 10% overpressure technology allowing users to set their valves closer to flowing pressures, minimizing product losses and maximizing profit. Made from aluminum, carbon steel and stainless steel, Models 12E and 12F are available in sizes from 2 through 12 in. (DN 50–300), in pressure settings from 0.866 to 41.5 in. water column (2.15–103.4 mbars), and vacuum settings of 0.803–41.5 in. water column (2.00–103.4 mbars). Tightness exceeds API 2000 leak requirements, the company says. — *Groth Corp., Stafford, Tex.*
www.grothcorp.com

Position sensors eliminate failures in valve control

This company's linear variable displacement transducers (LVDTs) are designed with an isolation-tube format (photo) to ensure reliable displacement feedback of hydraulic/non-hydraulic pumps and valves. The isolation tube protects the LVDT core from pressurized environments and fluids when the sensor measures pump flow or valve position (open/closed). The position sensor provides electronic feedback as part of a process control system. In the isolation-tube configuration, only the LVDT core lies inside the harsh area or media. Constructed of metal, the core can withstand exposure to a variety of fluids and pressures so that the chance of LVDT core failure is virtually nonexistent. With sensor windings in near ambient conditions, there is a low risk of unit failure. — *NewTek Sensor Solutions, Pennsauken, N.J.*
www.newteksensors.com

Gerald Ondrey

New Products

Enhance shift handovers with new AI-powered data engine

The Shiftconnector digital manufacturing platform (photo) now includes artificial intelligence (AI) search-engine capabilities. Shiftconnector's software platform is designed to enhance communications among shift teams for effective shift handovers, transparent team communications and increased asset performance. With the addition of AI-powered Smart Search capabilities to the Shiftconnector platform, teams will now be able to improve plant performance by quickly finding solutions based on the history of documented tribal knowledge from plant operations teams. By retrieving the most relevant information, it will accelerate operations and bring capabilities to help teams recover from disruptions by immediately identifying appropriate fixes. Also, captured knowledge can be managed to support workforce changes. — *Eschbach GmbH, Bad Säckingen, Germany*

www.eschbach.com

A new optimizer tool for wet electrostatic precipitators

This company has launched a digital optimizer for the Editube wet electrostatic precipitator (WESP). The new WESP Optimizer improves the operation of the WESP unit by better adjusting it to changes in the overall process, and has important built-in functions to protect units with plastic tube bundles (photo) during low acid-load operation, as well as during startup and commissioning. In addition, the Optimizer increases removal efficiency during high acid-load operation, and provides energy savings whenever there is spare capacity. The Optimizer also monitors the behavior of each WESP, enabling faster damage detection, and provides operators with otherwise unavailable information, such as calculated removal efficiency, says the company. The WESP optimizer continuously monitors the process conditions and provides a combination of automatic optimization of transformer rectifier (T/R) unit parameters, information and suggested actions for operators. — *Metso Outotec Oy, Helsinki, Finland*

www.mogroup.com

A smart way to detect spills and leaks

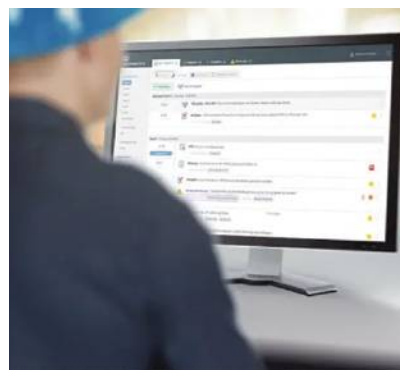
The SpillGuard leak-recognition system (photo) instantly alerts users when a leak is detected. This FM-approved technology is placed within the sump of a spill-containment device, or near the equipment to be monitored, and alerts users with an audible and visual alarm for a minimum of 24 h when contact is made with a liquid. Designed for use with all essential and common liquid hazardous substances, the explosion-proof SpillGuard features intelligent sensor technology in a highly resistant, electrically conductive housing. It is suitable for use at temperatures from 32 to 104°F, and has a red LED light to indicate that the unit is operating safely. It is ideal for use with containers and sumps of all sizes and types, as well as along pipelines, next to heating or cooling systems, beside hydraulic equipment, near industrial washing machines, adjacent to pump stations or anywhere that liquids are used or stored. — *Denios Inc., Louisville, Ky.*

www.denios-us.com

A new way to monitor safety-valve activity

The LiftTrack 2.0 (photo) is a new indicator device for pressure safety valves (PSVs) that enables users to capture data on the various lift events that occur within a safety valve. The LiftTrack 2.0 device is connected to the valve system and detects all lift events within each connected valve wirelessly, and also has the option to record acoustic outlet data or temperature coupled with the lift events. The mechanism records data on lift events and stores the information, which can be viewed in the manufacturer's app, so that users can better understand the PSV and overall system reliability. Capable of tracking multiple safety valves at a time, the LiftTrack 2.0 allows users to see what time the lift event occurred and track how long the safety valve was open, helping to mitigate the environmental release from each valve. This system is designed to work with relief valves, pressure-vacuum relief valves and other specialty relief-valve systems. — *Total Valve Systems, Broken Arrow, Okla.*

www.totalvalve.com



Eschbach



Metso Outotec



Denios



Total Valve Systems



Charles Ross & Son

This mixer features a new injection-manifold technology

Designed with efficiency and mobility in mind, the Model HSM-405SC-25 inline high-shear mixer (photo) features the Solids/Liquid Injection Manifold (SLIM) technology. The SLIM technology is a unique rotor-stator device capable of injecting powders directly into a fast-moving liquid stream without the use of an eductor or pump. Engineered for high-speed and high-volume mixing requirements, this device offers a straightforward method of wetting out powders and creating a fine dispersion, greatly reducing the occurrence of floating powders, lumps and agglomerates. The stainless-steel portable skid with built-in workbench allows the mixer to be used anywhere in a plant. This eliminates the need for multiple mixers that are separately dedicated to each vessel or product. As an external mixer, the inline SLIM system can be piped to the recirculation loop of virtually any size vessel. Featuring sanitary tri-clamp connections, this 3A-compliant machine can be cleaned in place, but is also quick to disassemble for deep cleaning and sanitation. — *Charles Ross & Son Company, Hauppauge, N.Y.*

www.mixers.com

Optimize boiler performance with these new air-gas flowmeters

The MT100 Series multipoint mass flowmeter (photo) provides air-gas flow measurements to help optimize boiler performance and reduce fuel consumption and greenhouse-gas emissions. These devices feature compact thermal-dispersion flow-sensor technology. They accurately monitor and report the flowrate or the totalized flow of air and fuel gases in order to achieve the precise combustion ratio necessary for optimum boiler performance that produces the steam for cracking and other high-heat petroleum refining and petrochemical production processes. The flowmeters come with one to eight flowrate-sensing points. The sensors are inserted at multiple locations along the boiler burner-piping assembly and their outputs are multiplexed and averaged to measure the air and gas flowrates and totalized flows. — *Fluid Components International LLC (FCI), San Marcos, Calif.*

www.fluidcomponents.com

This liquid analyzer is now high-temperature certified

This company has received TEX, IECEx, and UKEx certifications for its IRmadillo process analyzer (photo) for use in high-temperature liquid processes up to 220°C (428°F). These Ex certifications rate an analytical instrument as safe for use in hazardous environments, including potentially explosive atmospheres. This is a requirement for industries such as chemicals and petrochemicals, where the manufacturing processes frequently involve highly volatile and flammable components. The inline IRmadillo instrument has been designed to provide continuous, real-time analysis of liquid processes over a wider range of analyte temperatures in potentially explosive and hazardous atmospheres. — *Keit Ltd., Didcot, Oxfordshire, U.K.*

www.keit.co.uk

A new series of water sensors for nitrates and nitrites

The NT3100sc and the NT3200sc ultraviolet (UV) nitrate and nitrite sensors (photo) are designed with enhanced accuracy and a lower limit of detection at 0.02 mg/L. Leveraging reagent-free UV absorbance technology, NT3 Series sensors are equipped to meet a wide range of application needs, including measuring nitrate and nitrite in municipal sewage-treatment plants, surface water, untreated water or treated drinking water. The series includes three path-length options to fit users' individual measurement ranges and turbidity-compensation needs. The sensors operate over a temperature range of 2 to 40°C and up to 95% relative humidity. They also are IP68 rated. — *Hach Co., Loveland, Colo.*

www.hach.com

A new mid-range temperature sensor for tight tolerances

This company has launched a new specialized thermistor variant aimed at mid-range temperature-sensing tasks for tight-tolerance instrumentation in non-condensing moisture environments. The ENTC-EI-10k9777-02 thermistor (photo) is based on a Sty-cast epoxy-encapsulated core with Kynar insulation for maximum durability across a -40 to 125°C temperature range. Its high-sensitivity



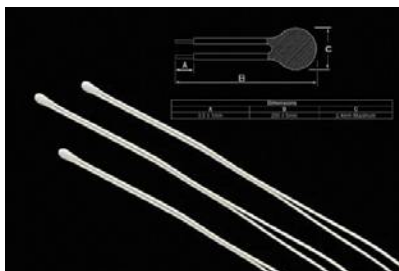
Fluid Components International



Keit



Hach



Variohm EuroSensor

specification of 10 k Ω at 25°C and $\pm 0.2^\circ\text{C}$ resistance tolerance up to 70°C delivers precision sensing for many industry sectors and instrumentation devices. The ENT-C-EI-10k9777-02 thermistor has a fast time-constant value of 1.5 s in liquids and a dissipation factor in still air of around 2 mW/°C. Measuring just 2.4 mm at its widest point and with 250-mm-long insulated, silver-plated copper leads, straightforward installation is guaranteed. — *Variohm EuroSensor Ltd., Towcester, U.K.*

www.variohm.com

Low-pressure dense-phase conveyor is stable and reliable

The E-finity (photo) is a continuous dense-phase conveying system for fragile materials. Precise pressure monitoring and air-flow corrections allow the system to operate efficiently under all conditions, while gently inducing materials through the conveying line in slug form. E-finity is suitable for granular and other pelleted materials, and has proven itself on many projects for pet foods, cereals, nuts, grains, prills and pelleted material. Unique E-finity air controls can employ a single air source to operate two to three different systems simultaneously. — *Schenck Process LLC, Kansas City, Mo.*

www.schenckprocess.com

Schenck Process



A new converter for HART to Ethernet-APL

The new Ethernet-APL HART Converter (HM-APL-PCB; photo) enables transmitter manufacturers to easily convert existing HART transmitters to the new Ethernet Advanced Physical Layer (APL) interface. The printed circuit board (PCB) can be customized to incorporate special features or size requirements. It is also possible to quickly design “direct to APL” transmitters without using HART.



ProComSol

The HM-APL-PCB consists of a ready-to-use PCB with a HART connector and an APL connector. Simply connect the HART transmitter to the HART connector to make the HART transmitter into an APL transmitter. The APL connection supplies all power needed for the PCB and the connected HART transmitter. — *ProComSol, Ltd., Lakewood, Ohio*

www.procomsol.com

New Profinet gateway for remote system redundancy

The new Profinet Gateways for the LB and FB Remote I/O systems (photo) enable the integration of Ethernet-based process control while providing access to complete diagnostic data. They support communication via HART on the instrument lines, connecting any data from the instrument with seamless integration of process data into any engineering or asset-management system. The new gateways feature S2 system redundancy for plants requiring high availability, connecting the remote I/O station to redundant controllers. This means that process control remains in operation even in the rare event of a controller failure or stop-



Pepperl+Fuchs

page. In addition, users can deploy gateways in ring redundancy. This provides protection from unwanted disconnects or faults in the installation. — *Pepperl+Fuchs SE, Mannheim, Germany*

www.pepperl-fuchs.com

Mary Page Bailey and Gerald Ondrey

C%Air-Moving Equipment for Pneumatic Conveying

Department Editor: Scott Jenkins

In a typical bulk-solids pneumatic-conveying system, an air mover is used to generate the necessary air flowrate and pressure required to transport a solid material through a pipeline at a given rate. This one-page reference discusses the operating mechanisms and characteristics of three different types of air movers for dilute-phase pneumatic conveying: centrifugal fans and blowers; regenerative blowers; and positive-displacement (PD) blowers (Table 1).

Centrifugal blowers and fans

Centrifugal blowers and fans are aerodynamic-type air movers, widely used on short-distance, very dilute-phase systems. The basic function of a centrifugal fan/blower is to produce kinetic energy by the action of centrifugal force. Its impeller and channels convert this kinetic energy of the air into potential energy (in the form of pressure) by efficiently reducing the velocity of the flowing air. The air flowrate is highly dependent upon the conveying-line pressure drop.

The solids-to-air ratio for a fan conveying system is typically less than 1.2 to 1. If its feedrate is steady and smooth, the solids-to-air ratio can be up to 2 to 1. Fans may be used for both positive-pressure and negative-pressure conveying systems. The centrifugal fan/blower used in pneumatic conveying applications are normally of the radial, flat-bladed type. At a given speed, these centrifugal fans or blowers will draw the same volume of air at a given pressure.

Regenerative blowers

Regenerative blowers are also aerodynamic-type air movers, and are mainly used on short- to medium-distance, dilute-phase systems, such as drum/bag dump stations and solids conveying eductors. A regenerative blower impeller consists of numerous radial blades along the circumference of the impeller. The impeller spins within a housing that consists of inboard and outboard "channels." As the impeller passes the inlet port, air is drawn in. As the impeller rotates, air is

TABLE 1. COMPARISON OF AIR MOVERS FOR PNEUMATIC CONVEYING					
	Mechanism	Inlet capacity, actual ft ³ /min	Maximum discharge pressure / vacuum	Operating speed, rpm	Maximum power, hp
Centrifugal fan/blower	Dynamic	60 – 250,000	14 – 128 in. H ₂ O column	800 – 3,800	1,600
Regenerative blower	Dynamic	40 – 900	13 psig 14 in. Hg	2,000 – 4,500	120
Rotary lobe blower	Positive displacement	15 – 30,000	5 – 25 psig 18 in. Hg	300 – 4,000	500
Rotary screw compressor	Positive displacement	120 – 58,000	15 – 700 psig	1,000 – 20,000	8,000

captured between each blade on the impeller and is pushed both outward and forward into the channels. The air then returns to the base of the blade. During this process, a portion of the kinetic energy (air velocity) is converted to potential energy (air pressure). This process is repeated over and over as the impeller spins. While each blade-to-blade regeneration "stage" results in only slight pressure increases, the sum total, from air entry to outlet can yield continuous operating pressures of up to 13 psig or vacuum to 14 in. Hg. Regenerative blowers have parallel inlets and outlets that are positioned perpendicularly to the rotation of the impeller.

The solids-to-air ratio for a regenerative blower conveying system is typically less than 4 to 1, and its maximum air flowrate is about 900 ft³/min. Regenerative blower installations typically have a direct-drive design, but can also be belt-driven. Among the benefits of a regenerative blower is that it is virtually maintenance-free. There is only one moving part (the impeller), which does not come in contact with the housing channel and is essentially wear-free. Regenerative blowers generate little vibration and noise and can operate for up to 40,000 hours without requiring service.

Positive-displacement blower

Positive-displacement (PD) blowers are probably the most commonly used type of compressor for dilute-phase pneumatic conveying systems, where the operating pressure typically does not exceed about 18 psig. That pressure is an ideal match with the pressure capability of conventional rotary valves. The PD blower is es-

entially a constant-speed machine that delivers a relatively constant volume of air over a range of discharge pressures. The solids-to-air ratio for a PD blower dilute-phase conveying system is typically from 2 to 1 to 6 to 1, up to 10 to 1 in some cases. PD blowers have also been used for short-distance, dense-phase pneumatic-conveying applications, such as hopper truck unloading. The resistance of the system to which the blower is applied determines the operating pressure.

The twin-lobe Roots-type blower is the oldest and most widely used PD blower. It consists of a pair of involute profiled (shape of 8) lobes/rotors that rotate inside an oval-shaped casing. One lobe is the driving lobe, which is powered by the external power source, while the driven lobe is driven by a pair of equal-ratio gears. Both lobes rotate at the same speed, but in opposite directions. As the rotors rotate, air is drawn into the inlet side of the cylinder and forced out the outlet side against the system pressure. With each revolution, four such volumes are displaced. The displaced air is not allowed to return due to the small internal clearance within the internals of the machine (except for a very small amount called "slip"). No compression takes place in the machine. However, as the discharge end is reached, compression occurs when the high-pressure air in the outlet pipe flows back and meets the trapped air. Due to this shock compression, the thermodynamic efficiency of the machine is relatively low, and it generates relatively high pulsation and high noise. ■

Editor's note: The text shown here is adapted from the following article: Liu, G., Air Movers for Dilute-Phase Pneumatic Conveying, *Chem. Eng.*, October 2019, pp. 56–62.

Advanced mixing solutions for chemical plastic recycling

Well over eight billion tons of plastic have been produced worldwide in the last 70 years, most of it since the turn of the millennium. Careless use of plastic has escalated into a global environmental problem. Unfortunately, the following applies to the vast majority of polymer products: regardless of the form in which they are introduced into nature, degradation under atmospheric conditions does not take place at all or only extremely slowly. This endangers the environment to a large extent. Especially the oceans are particularly affected by the significant amounts of plastic waste. In the meantime, complete “plastic islands” have emerged in unimaginable proportions in the North and South Pacific.

Due to this global challenge, the recycling of plastics is increasingly becoming the focus of the general public. The goal should be a “circular economy”, i.e. ideally a worldwide, closed cycle of plastic products.

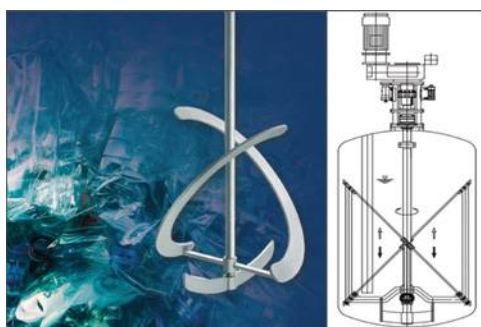
Currently, recycling is mainly carried out using mechanical processes. The largest, widespread plastic waste fractions contain many impurities, metals, additives, dyes or multi-layer films. To successfully return these mixed fractions to a cycle, both mechanical and chemical plastic recycling processes must be established on a large scale.

Basic process challenges in plastic recycling

In the first process step of the respective recycling process, the input material for the dissolving or melting process must be prepared in such a way that trouble-free operation and a reproducible process result can be achieved. Due to the sometimes strongly varying nature of the plastic waste, this is exactly where the first, major process challenge lies.

Not only the quality and “purity” of the input material usually vary to a large extent, but also central parameters such as bulk density, particle size or the wettability of the starting material play a decisive role.

Depending on the process, very high viscosities or even higher rheological challenges, such as yield points, are to be expected. In such demanding media, not only the general mixing task such as homogenization and suspension, but also the heat transfer should function reliably. Sophisticated and efficient stirring technology is required if the initial mass is to be homogenized accordingly and brought to the required process temperature in the reactor.



Mixing solutions using the EKATO PARAVISC impeller

For high-viscosity products, wall-scraping, forced-conveying mixing systems are typically used. It is important to ensure the shortest possible mixing time in the laminar flow area. Traditionally, these are often helical or anchor impeller systems. Modern mixing systems such as the EKATO PARAVISC deliver significantly shorter mixing times and thus significantly better process results.

The EKATO PARAVISC impeller for highly viscous products and example of a reactor solution based on the EKATO PARAVISC

With the EKATO PARAVISC, axial mixing is achieved through the unique shape and arrangement of the two main blades. Depending on the application, this agitator can be operated both upwards and downwards. For example, if it conveys downwards, the fluid is pressed down the wall, changes its direction of

movement on the bottom and flows towards the surface in the area of the agitator shaft.

Link You Tube: <https://youtu.be/YNwiSWI9HPo>

Customized reactor concepts from EKATO

For certain chemical recycling processes, such as thermal processes or PET recycling processes, some processes are already being established well beyond the pilot scale.

Some solvent-based processes (solvolysis) as well as different catalyzed processes are meanwhile on the way from the pure, promising process idea to a pilot plant.

At this point, EKATO offers the principle of the tailor-made reactor concept. On the basis of “Joint Development Agreements”, reactor concepts are developed from the customer processes - which have been tested in the laboratory - and implemented as a scalable, modular system on a pilot scale.

EKATO supports innovative companies in the development of depolymerization technologies with its know-how and expertise in mixing and reactor technology. Processes with different types of plastic waste can be tested and optimized under realistic conditions on a technical scale in the EKATO technology center or in pilot plants tailored to the respective customer process. Based on the findings from pilot tests, EKATO develops a reactor system tailored to the needs of the customer.

More Information under: www.ekato.com/processes/chemical-recycling-of-plastics/

Temperature: The Most Misunderstood Process Variable

Measuring temperature is required in nearly all chemical processes, but engineers often struggle with implementation. Here are suggestions to avoid common pitfalls

**Greg Pryor and
Kris Worfe,**
Endress+Hauser

IN BRIEF

WHERE TO MEASURE?

SOLVING MULTIPOINT
MEASUREMENT

EFFECTIVE RESULTS

SENSOR
CHARACTERISTICS

AVOIDING SIGNAL
DEGRADATION

DIAGNOSTIC
CAPABILITIES

CREATING BETTER
APPLICATIONS

Measuring temperature in chemical processing applications remains, arguably, the most misunderstood of the four main process variables, which are flow, level, pressure and temperature. Complexity arises from process requirements of an application — such as where and how to locate a sensor — and from the sensing technology itself.

In this article, we examine one particularly challenging application that incorporates many application-side problems, then dig into sensor and transmitter capabilities and trade-offs.

Where to measure?

One of the challenges of temperature measurement is dealing with process inconsistencies. Temperature is rarely homogeneous. For example, imagine a large vessel of liquid: natural convection will cause stratification such that the contents near the bottom will likely be cooler than at the top. So, where is the ideal place to take a temperature measurement?

In the real world, the answer may be everywhere. Say the vessel is a reactor and feedstocks mix over a catalyst bed to create an exothermic reaction. A process engineer attempting to optimize the reaction will want to determine a temperature profile throughout the contents, since it indicates how and where the feedstocks are interacting. Temperature details help determine if the reaction can be made more efficient, if the feedrate needs to be changed, or if some other configuration element should be modified.

Temperature, under these conditions, cannot be measured from a distance, and a single temperature sensor can only measure its immediate surroundings. If many readings are desired throughout the vessel in different locations — such as in a distillation

tower or reactor — multiple sensors are required at those strategic points. This means if a location one meter inside the vessel is required, there must be a 1-meter-long probe. And if fluid is moving around inside, or flowing through a pipe, the probe must withstand the movement. Given these mechanical challenges, plus possible interference from agitators or level measuring devices, it is no wonder complex multipoint measuring challenges are some of the most difficult to solve.

Solving multipoint measurement

An effective multipoint solution must fulfill the following list of process requirements:

- Probes extending into the vessel interior must have sufficient mechanical strength to avoid breaking, and they must be made from materials capable of withstanding the temperature and chemical environment
- A probe can and often should include multiple temperature sensors (Figure 1) along its span to minimize the number of penetrations while increasing measurement points. Probes can also be curved where practical



Endress+Hauser

FIGURE 1. Some applications call for individual probes stemming from a common mount that can be bent as needed to cover the space

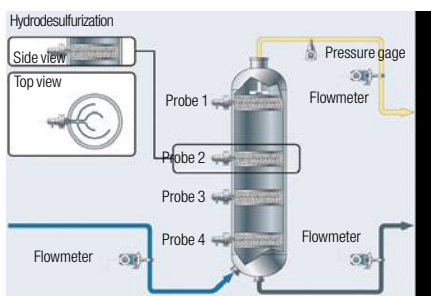


FIGURE 2. Using a multipoint temperature probe (right), a petroleum refinery created an accurate temperature profile for a catalyst bed (left) without causing obstruction problems

to improve placement options

- Identical sensors must be used in each location, plus probe wall thickness must also be uniform, to deliver consistent and accurate readings with similar response time. It is only under these conditions that an accurate and dynamic temperature profile can be determined

Putting these requirements into practice means balancing multiple trade-offs, as follows:

- While a resistance temperature detector (RTD) generally offers more consistency and accuracy than a thermocouple (TC), TCs tend to win out in multipoint applications due to their durability, fast response, and ability to pack into compact packages with minimal insulating material
- Probe materials must be corrosion resistant. However stainless steel and other exotic alloys frequently have low thermal conductivity, slowing response time. Adding wall thickness for strength and internal protective insulation makes the problem worse, so careful probe design is critical
- Probe locations must minimize internal blockage, particularly in areas near catalyst beds
- Constructing probes as thermowells allows for sensor removal, but also usually results in thicker walls and internal gap. This results in slower response

Effective results

Building highly-effective probes requires expertise and optimum component selection, but the positive results speak for themselves. A petroleum refinery wanted to develop a temperature profile across the catalyst bed of a hydroprocessing unit that routinely handled crudes with significant hydrogen sulfide content (Figure 2). In this aggressive environment, corrosion of probes and wiring

is a constant issue, causing temperature measurement inconsistency and outright sensor failure.

After an examination of optimal sensor placement, it was possible to design probes to reach all strategic measurement locations with minimal catalyst bed blockage. Clever probe design — using a hydrogen sulfide-resistant alloy in addition to internal wire protection — made it possible to deliver sensors that withstand the harsh environment, while providing consistent and directly comparable readings, capable of generating a true temperature profile necessary for process modeling and analysis.

Sensor characteristics

The debate of TC versus RTD as an ideal universal sensor technology continues, but fortunately, there is no need to make an either/or decision. Each has its niches, depending on process requirements, although the parameters of the traditional discussion are always evolving. The two methods are conceptually different, and they are worth a brief look (Figure 3).

A TC works on the basis that a wire subject to a temperature gradient also creates a corresponding voltage gradient, and different alloys respond differently to the same tem-

perature gradient. Consequently, a TC uses two dissimilar alloys, joined at one end, as the sensor. Temperature is calculated based on the voltage difference, but to determine the absolute temperature at the sensor, there must be a known temperature reference. This is where the terms “sensing” (hot) junction and “reference” (cold) junction, two ends of the electrical circuit, are derived from.

TCs are easy to make, and can be optimized using specific alloy combinations (designated as types) to cover different ranges. Generally, TCs are valued for fast response and durability. However, they often take a back seat in accuracy and repeatability, because any change in the electrical characteristics of the wires can cause a reading shift or drift. Drift is typically the result of corrosion at some point along the lengthy electrical path.

An RTD operates on the basis that various metals change electrical resistance according to temperature. Platinum is very good for this purpose, and the sensor uses a tiny coil of fine platinum wire as the sensor. The circuit measures resistance, and to avoid changes related to the lead wire's resistance, multiple lead wires — usually three or four — cancel out this element electrically. RTDs are valued for their accuracy and repeatability. However, they are more fragile and the protection they require slows their response time.

New manufacturing techniques have resulted in more robust RTDs that do not require as much protective insulation, providing faster response times. And for TCs, improved electrical insulation better protects lead wires from corrosion, resulting in less severe drift.

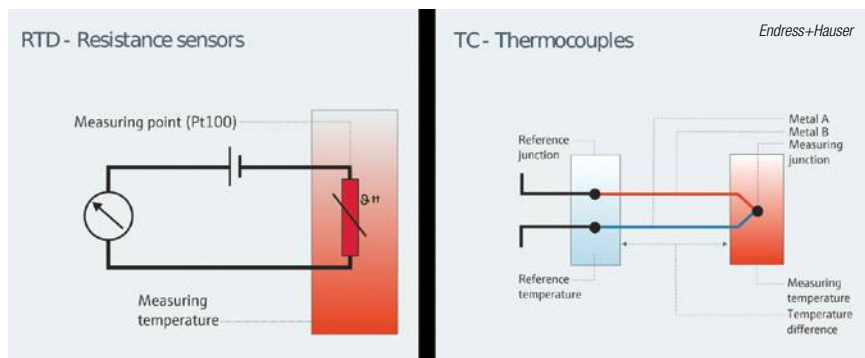


FIGURE 3. RTDs (left) and TCs (right) are different conceptually. TCs modulate voltage, whereas RTDs modulate resistance. Both require specialized cables to send their measurement over any distance



FIGURE 4. Measurements taken in a moving liquid stream by a sensor encased in a thermowell tend to be slow due to heavy protection, but modern variations, like the probe pictured, provide durability and strength without sacrificing response

For example, a food processor switched to modern, fast-responding RTDs (Figure 4) for an ultra-high temperature treatment process. After a series of tests, plant engineers found these new sensors reduced response time by more than 50% compared to previously installed

sensors. This allowed for tighter temperature control, maintaining the process within a very narrow range necessary to optimize production.

Avoiding signal degradation

The signals created by RTDs and TCs are not very robust, and they

can be difficult to transmit over long distances without degradation. In fact, most problems related to drift are more attributable to wiring and termination issues than sensor problems. Additionally, temperature sensors require specific, homogenous cabling that is specialized, and usually very expensive.

For this and other reasons, it is typically most practical to install a temperature transmitter as close to the sensor as possible, to convert the raw voltage or resistance signal to a more transmittable format. For example, when measuring moderate temperatures, most TCs create a signal less than 15 to 20 mV, so a very small change can represent a significant temperature movement.

A transmitter turns the raw analog output from the sensor into a more robust signal, such as a 4–20-mA current loop or digital fieldbus. Some transmitters are dedicated specifically to RTDs or TCs, but most are universal and can handle resistance



FIGURE 5. Advanced transmitters monitor sensor health and can perform signal conditioning in the field, before signals even make it to a host automation system

or millivolt inputs. When working with TCs, a transmitter provides an internal reference junction and can be set to convert multiple TC types. These versatile internal capabilities also help provide instrument diagnostic information.

Transmitters come with a variety of options, and at the most basic level, simply convert the sensor output into a communication-optimized format. For many applications, this may be all that is necessary, and this usually costs less than buying spools of specialized cable required to connect multiple sensors to the automation host system.

The “hockey puck” configuration, mountable on a sensor, is very common in chemical plants. But for hazardous locations, separate housings are often required, frequently with a local display.

Most transmitters can work with RTDs or TCs, and can be configured using the HART communication protocol superimposed on the 4–20-mA analog current loop, or via another digital protocol, such as Foundation Fieldbus or Profibus PA. Additionally, modern “smart” transmitters enable configuration wirelessly via Bluetooth, requiring only a smartphone or tablet application to set up.

Diagnostic capabilities

Today’s sophisticated field instruments provide diagnostic capabilities, but there is little consistency in the ways these work from manufacturer to manufacturer. Some have adopted the NAMUR 107 standard to create a higher degree of uniformity when presenting diagnostic informa-

tion, so reliability teams and operators can more easily understand what a device is communicating. This includes notifying users when a sensor needs to be checked, when maintenance is required, when measurement accuracy falls out of specification, or when an instrument fails outright.

Temperature transmitters have specialized diagnostics that differ from pressure or flow instruments. Highly sophisticated transmitters, such as the one shown in Figure 5, can examine sensor health and perform signal conditioning at the field level, before even sending a process value measurement to the host automation system.

The following are examples of diagnostic features:

- A single transmitter can accept signals from two identical sensors installed as a redundant pair. It compares the two, and if the values begin to diverge, it can notify operators of a developing issue
- When two sensors are in use, if one fails, the transmitter can maintain the operating sensor while alerting operators of the other failed sensor
- If leakage to ground is detected anywhere in the loop, the transmitter can create an alert
- Where a TC is in use, the transmitter can use its resistance measuring capability to check the lines periodically. If a resistance change is detected, the measurement is likely questionable
- Some transmitters can log readings over multiple days, helping troubleshoot situations in which readings change without a process-related cause

Creating better applications

When analyzing a new temperature-measurement application or trying to

improve an existing one, it is important to consider a variety of questions. These often include the following:

- How critical is the measurement? Is it being used for control, or simply monitoring? This helps determine the need for redundant sensors, sophisticated diagnostics and other reliability considerations.
- How accurate must the measurement be, or is consistency equally useful?
- How quickly can the process temperature change, and how much does it move? If the process does not move quickly and avoids wide swings, ensuring fast response may not be necessary.
- Will alarming or safety elements be attached to this measurement? Many sensors and transmitters are safety certified, but their use does not automatically result in a proper safety-instrumented function.

By partnering with a knowledgeable supplier, processors can sort through these questions, determining relative importance and balancing trade-offs. These considerations can enhance understanding of the complex topic of temperature measurement, helping optimize applications for product quality, plant sustainability and production profitability. ■

Edited by Scott Jenkins

Authors



Greg Pryor is the product marketing manager for temperature and systems products at Endress+Hauser USA (2350 Endress Place, Greenwood, IN 46143; Phone: 888-363-7377 Email: info.us@endress.com). He has national responsibilities for the strategic direction of the temperature business unit, including

product portfolio management, technical and application support, and marketing and business development for temperature and systems products. He has a bachelor of business administration (BBA) degree in marketing from Texas A&M University. Based out of Houston, Texas, Pryor has over 20 years of experience in temperature measurement instrumentation.



Kris Worfe is the chemical industry manager at Endress+Hauser USA (same address as above). He has national responsibilities for the strategic direction of the chemical business, including product portfolio management, technical and application support, and marketing and business development for the

chemical industry. He has a BBA from Texas A&M University. Based out of Houston, Worfe has over 22 years of process automation experience.

Non-Invasive Temperature Measurement in the CPI

While thermowells have become well-established, they have potential drawbacks that can affect their performance. The benefits of alternative non-invasive temperature sensing is presented [here](#)

Guruprasad Sosale

ABB Measurement & Analytics

Temperature is one of the most important parameters for industrial processes, providing a key indicator of system safety, product quality and overall process efficiency, as well as equipping operators with the information they need to ensure their plant is running at optimum performance. As such, temperature should ideally be measured as widely as possible to provide the best possible overview of process conditions.

This article discusses the limitations of conventional thermowell technology and how non-invasive temperature measurement has advanced to become a cost-competitive alternative.

Thermowell issues

In the chemical process industries (CPI), thermowells are often selected as the preferred method for temperature measurement. Essentially metal sheaths that protect the measurement sensor against the process being measured, thermowells have become commonplace throughout the CPI, being used in everything from food-and-beverage through to oil-and-gas processing. While thermowells can be effective in protecting the temperature sensor, their use is not without problems.

Foremost among these problems is the need for them to be in physical contact with the process medium, which means first shutting down the pipeline and then drilling a hole through which the probe can be inserted (Figure 1). This may also require the addition of flanges

or fittings to help maintain pipeline integrity and satisfy safety requirements. While these devices have typically offered accurate and reliable performance, the time, cost and disruption associated with their installation has tended to limit the widespread measurement of temperature in a process.

Aside from cost and time, the installation of thermowells can also pose safety risks, especially in applications where liquids may be flowing at high speeds, high pressures or both, which could cause injury if the pipeline is not properly shut down.

Another challenge has been the potential complications arising from the characteristics of the medium being measured. Substances can be liquid, gaseous or in viscous or semi-viscous states, or, in some cases, a combination of these, flowing at different rates. These substances can vary in their characteristics, ranging from benign liquids, such as water, to aggressive chemicals or abrasive mixtures. In each case, the design of the temperature device used needs to be able to withstand the rigors of the application to provide reliable and safe operation.

Where thermowells are used to protect temperature sensors, they must also be designed for the characteristics of the medium being measured to help safeguard



FIGURE 1. Thermowells require boring a hole in the pipe and bolted flanges to support the temperature sensor

the temperature sensor against chemical and mechanical stress. An example is abrasive components suspended in a process. When moving through piping at high speeds, abrasive particles can subject the thermowell to scouring that can reduce its operational life over a prolonged period. While using special thermowell materials can help to tackle this, it can also add substantially to the overall price tag. To protect against the effects of abrasive and chemically aggressive media, thermowells must be regularly inspected and replaced if necessary.

To avoid problems such as premature wear and potential failure, thermowells must be regularly inspected and replaced if necessary, adding to the costs. These inspections require



FIGURE 2. Unlike thermowells, non-invasive temperature sensors are mounted outside the pipe, so there are no issues related to contact with the fluid inside the pipe

at least a partial shutdown, usually requiring complete emptying of the system. Thermowells also need to be cleaned, which can incur further costs, including those resulting from having the pipeline shut down while the probe is removed.

In addition to increased costs, using thermowells can also have safety implications. A thermowell placed in flowing media, for instance, can begin to vibrate due to vortex formation. In extreme cases, this vibration can lead to the thermowell breaking, which can have dramatic consequences, not only for the system, but also for the whole operating environment.

Consequently, the standards governing the stability of thermowells, such as ASME PTC 19.3 TW-2016, have become ever more restrictive, increasing engineering costs and restricting the ability to use conventional thermowells in some cases.

Given these factors, it may come as a relief to know that a thermowell may not even be necessary in many cases, due to non-invasive sensor technology (Figure 2).

Principles behind non-invasive

To understand how non-invasive temperature measurement technology works, it is necessary to first understand the physics of a typical pipe line where a liquid or liquid-like mixture is flowing. The behavior of a flow in a pipeline is known as the flow profile. There are three main categories of flow profile, each related to the velocity of the liquid. These categories are termed as laminar, transitional and turbulent.

Laminar flows occur at stable,

low flowrates, with the fluid moving in the same direction at a constant speed. The fluid settles into streamlined tiers, which are prevented from moving by the viscous forces within the liquid, and the flow velocity increases in a well-known parabolic profile from the wall to the center of the cross section, with a relatively distinct boundary layer.

Transitional flows occur when the increased velocity of the fluid causes distortions in the flow, leading the tiers within the fluid to become mixed. This mixing causes the flow to show both laminar and turbulent characteristics at different points in the pipeline.

Turbulent flow occurs at faster flowrates, where eddies and whorls cause mass distortions by forming their own separate sub-distortions. These mass distortions cause the tiers within the fluid to blend. The resulting average velocity profile is constant across the majority of the cross section with a very small boundary layer thickness.

In a simplistic manner, the temperature difference across the cross section of the fluid follows the general flow profile. The difference between the bulk fluid temperature and the inner wall of the pipe is largely determined by the boundary layer thickness.

As turbulent flow is the most common type of flow profile in industrial applications, it is this type of flow that presents interesting possibilities for temperature measurement. Physics models of the temperature distribution demonstrate that in contrast to a laminar-flow regime, where the representative temperature is

dictated by the boundary layer, a turbulent flow regime would have the temperature evenly distributed throughout the flow, with little difference between the temperature in the center of the pipe and the temperature at the pipe wall. For a metal pipe, the inner- and outer-wall temperature in such a flow case would have a negligible temperature difference — in a similar manner to electricity, metals are extremely good conductors of heat.

The vast majority of existing piping and in plants to come are and will continue to be metallic. This makes non-invasive surface temperature measurement an increasingly attractive option for process measurement applications, where around 70% of installations feature turbulent, rather than laminar, flows. To date, the challenge has been to accurately capture the surface temperature of the piping and the dynamic temperature changes.

Engineering tools that can be used to calculate the temperature difference between the surface and the medium are now available [1]. Advanced features enable factors such as the effect of flow, density viscosity, pipe diameter and even ambient effects to be included to help determine how good a surface measurement can be.

The benefits of non-invasive

Devices to measure the surface temperature piping are not new. So-called “skin temperature” sensors, for example, which measure the temperature at the pipe wall, have been available for a while. These devices typically employ either thermocouples or resistance temperature detectors (RTDs) that can be mounted on the pipe surface. While these can be effective, their performance tends to be hampered by poor design, poor location, or bad installation, reducing their accuracy and response times. If not properly insulated, they can also be sensitive to ambient conditions that can affect their measurement accuracy. Improving performance also dictates a mounting along the pipe under the insulation. In contrast to thermowells, this can make it even more difficult and costly to investigate or replace sensors in the field.

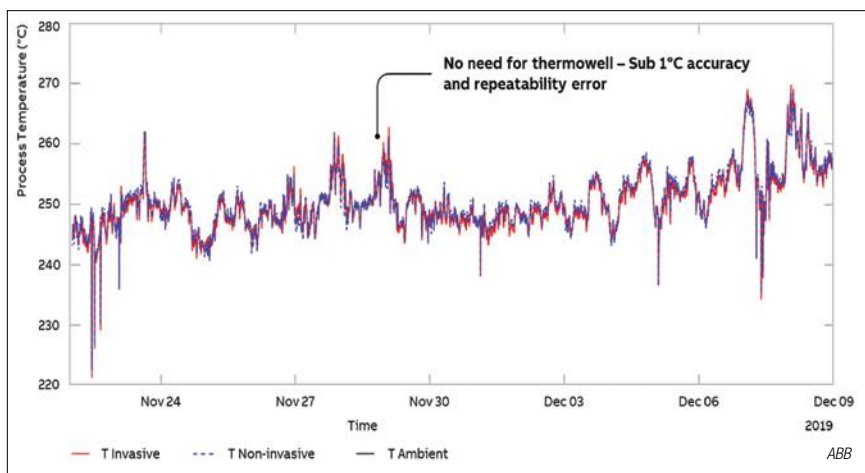


FIGURE 3. Plotted here is the temperature trend of superheated steam on a distribution line heat exchanger for district heating in a city in Germany to compare an invasive thermowell with non-invasive temperature sensor mounted at the same location. Difference (non-invasive – invasive): accuracy (mean) = +0.24°C, repeatability (standard deviation) = 0.65°C; pipe: DN125, steel; process: superheated steam 270°C nominal, 7,000 kg/h flow speed; thermowell: 3G tapered 2-mm tip

Achieving a true surface measurement calls for something that can factor out the potential errors that can affect the temperature reading and some means of being able to simplify mounting and maintenance

of the sensors. This is now possible with the latest generation of surface-mounted temperature-measurement technology. One commercial non-invasive temperature solution, for example, uses the same sensor

and transmitter technology as in a thermowell installation, but with a model-based approach that digitalizes the actual thermowell itself.

The software measures the readings from dual sensors — one measuring the temperature of the pipe wall, the other measuring the ambient temperature — and uses the resulting data to calculate and output the true surface temperature in real time. By taking account of the ambient conditions during the measurement, and with a predictable contact resistance, the transmitter significantly increases the accuracy and the responsiveness of the surface measurement. When coupled with offline models that predict the difference between the process temperature and the surface temperature, this sensor eliminates the need for a traditional measurement.

The effectiveness of this technique compared to a conventional thermowell has been demonstrated in thousands of installations

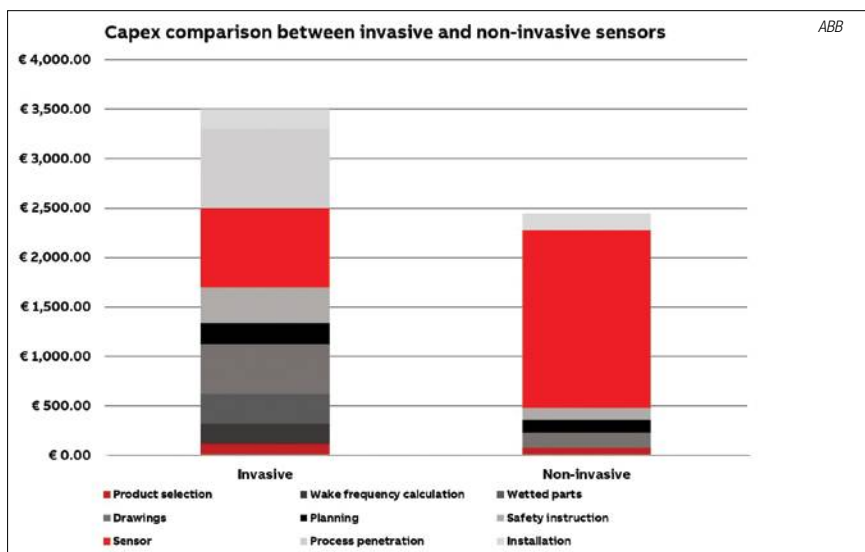


FIGURE 4. New-generation non-invasive temperature sensors can achieve cost savings of at least 30% by either minimizing or eliminating much of the time and effort required to plan, design and install a classic thermowell installation

across the world. The availability of performance-prediction models show the efficacy of the principle for measuring a wide variety of processes. From simple auxiliary fluids like cooling-water monitoring on heat exchangers to high-temperature, high-pressure steam measurements (Figure 3), the use of the non-invasive sensing is broken down into two simple steps. The first is to check the expected performance of a surface measurement using online prediction tools (input common process parameters such as flow, density, viscosity and so on). If the difference is applicable and acceptable, the second step is to use an accurate, repeatable, robust measurement device that compensates for common errors in surface measurements.

Save time and cost

The advantages offered by this new generation of non-invasive temperature sensor offers the potential for significant cost savings compared to a classic thermowell installation. Savings of at least 30% can be achieved by either minimizing or eliminating much of the time and effort required to plan, design and install a conventional invasive temperature sensor (Figure 4).

Much of this can be attributed to the easy-fit nature of the sensor. The sensor is designed to be mounted on the surface of a pipe, avoiding the time, cost and disruption involved in fitting a conven-

tional temperature sensor. There is no need to drill into the pipelines, because the sensor is attached to the pipe by two clamp collars. This installation arrangement also helps to reduce the amount of insulation needed, with just the foot of the device needing to be covered. As a result, the sensor can typically be installed in under an hour, enabling operators to quickly get up and running.

There is also little of the work associated with specifying and installing a thermowell, which can often take several weeks from start to finish. One major area that is eliminated is the need to carry out wake frequency calculations, which are needed for invasive installations to assess the design of the thermowell device including its size and the type of material needed to withstand the impact of the process medium. The need for such calculations, together with the associated process adjustments, can typically increase the total price tag of thermowells by two to three times over and above their material cost.

Final remarks

While temperature may be one of the oldest process measurements, it doesn't follow that the way that it is measured must stay the same. When it comes to temperature, the conventional approach to measurement is increasingly being challenged by the new possibilities

that digitalization is bringing to all areas of industrial measurement.

Advances in temperature measurement technology, particularly when it comes to digitalization, are presenting new opportunities for disruption that can benefit the vast majority of companies operating processes with turbulent flows. By switching from analog to digital, companies can benefit from the integration and application of process data across the plant, enabling them to make informed decisions on everything from plant operation through to maintenance.

As this article highlights, the many benefits offered by non-invasive temperature sensors address many of the traditional drawbacks of conventional measurement methods that have prevented temperature being measured more widely across process plants. Combining high performance with the flexibility to be deployed anywhere, non-invasive temperature sensors promise to unlock new opportunities for enhanced plant efficiency.

Going forward, developments in non-invasive temperature measurement will enable companies to transform their ability to measure an expanding range of flow regimes and fluids with more complex heat-transfer behavior, such as gases, with the same levels of accuracy, reliability and responsiveness as thermowells. ■

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Author



Guruprasad Sosale is the global product manager for non-invasive and wireless technologies at the ABB's business unit Measurement & Analysis Technology (Landsberger Strasse 320, Munich, Germany 80687; Phone: +49-89-58005-0). Prior to assuming this role in October 2022, he was senior scientist, Industrial Sensing Technology, at ABB's Corporate Research Center in Ladenburg, Germany. The focus of his R&D activities were wireless and autonomous sensors, and then non-invasive sensor technology, which also includes temperature measurement using ABB's NiTemp. He was part of the NiTemp development team and now has the role of bringing this technology to market. Sosale earned his Ph.D., M.Eng. and B.Eng. degrees in mechanical engineering from McGill University (Montréal, Canada).

ESG Programs: Understanding the Untapped Opportunities

While it may be easy to fixate on the costs and efforts associated with implementing ESG programs, taking a closer look at ESG can reveal many untapped advantages

Environmental, social and governance (ESG) programs are intended to encourage companies to act in a responsible manner (Figure 1). With the increasing importance among investors, special interest groups and regulators, it is vital to understand what ESG represents, as well as related trends and how to use it to gain a competitive edge. ESG investing has been defined as, “a strategy you can use to put your money to work with companies that strive to make the world a better place” [1]. Each company generates and shares its own ESG report card, which is typically verified by an independent third party and addresses the three ESG pillars accordingly.

Environmental. This describes how the company is working to minimize the impacts from its operations on the environment. This is something that can go beyond direct operations and often includes how vendors and subcontractors are selected. In addition, suppliers should be evaluated, since this effort can not only identify potential environmental concerns, but can also help an organization protect its own interests relative to raw-material quality and availability, and can identify and reduce risk where organizations rely on their supplier stock for their own product development.

Social. ESG-driven companies are focused on how they can use the influence of their business and brand to change communities for the better. This can include a wide range of social issues, but should also be something that has meaningful impact and is supporting a cause much bigger than the company. Companies that take the lead on identifying their own social influences can influence consumers looking for responsible organizations to invest and buy from as a means of exerting their buying powers. In 2018, the Edelman Earned Brand Study found that values-based communication is as effective as product-based communication in driving purchase intent, “and a communication focused on a brand’s stand has an even greater effect on a consumer’s intent to advocate for the brand than one

focused on product features” [2].

Governance. This refers to how the company’s management is setting the example for positive change within the organization. This can range from how executive pay is managed to hiring diversity, equity and more.

With a few exceptions, the regulatory environment is moving toward full reporting of ESG-related functions. This can be felt in the U.S. with newly promulgated regulations from a wide range of governing bodies, such as local, state and federal agencies like the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA) and the Securities and Exchange Commission (SEC) [3]. Some examples of how these regulations are slowly changing over time can be highlighted through recent proposed rule changes by the SEC for publicly traded companies. Until recently, publicly traded companies were only required to report ESG-related issues that were material to the business. This reporting framework was in place since 2010 and has undergone updates since President Biden signed the Executive Order on Climate-Related Financial Risk in 2021. The SEC also proposed a rule in May 2022 on climate-risk disclosures, which require companies to report Scope 1 and 2 greenhouse gas (GHG) emissions beginning in 2024. On a state level, California has passed the Climate Corporate Accountability Act, which requires approximately 5,200 public and private companies to report GHG emissions.

Most professionals agree with the importance of a well-run business that embraces environmental stewardship, social responsibility and good corporate governance. There are, however, some who take exception to this type of agenda being mandated as a regulatory requirement, because the data collection and reporting can be a costly expense. It is important to realize that, if ESG initiatives are fully embraced, a competitive advantage will begin to emerge that will allow companies to benefit from these perceived regulatory burdens.

Curtis Shakotko
OneSourceEHS

IN BRIEF

LOWER COSTS, HIGHER PROFITS

SUPERCARGE YOUR ESG LAUNCH

CREATING MOMENTUM

ESG SUCCESS STORIES



FIGURE 1. ESG programs can help companies to identify and prioritize their values while also improving financial performance

Lower costs, higher profits

Many believe that ESG initiatives are great for large, publicly traded companies with an abundance of resources, but that they are not worth implementing for a small or medium-sized company. This is a common misconception that may be keeping such companies from obtaining a wide range of benefits. The following are several benefits to consider:

- **Cost control** — A poll conducted within industry regarding the financial benefits of implementing a formal environmental managing process developed by the International Organization for Standardization (ISO; Geneva, Switzerland; www.iso.org), ISO 14001, showed that the average operating cost ratio decreases by approximately 6% [4].
- **Improved profit margin** — The same study reported that the average operating profit margin was increased by 2.2% after adopting a formalized environmental management system [4]. It is clear that following ESG frameworks provides generally positive results, summarized in Figure 2 [4].
- **Good management practices** — The benefits of a solid ESG program can be succinctly described: “Sustainability is neither a program nor an initiative, it’s considered simply good management” [5]. Again, sustainability is becoming important to both consumers and shareholders hoping to influence practice with their investments and spending.
- **Employee retention** — For example, consider a company complying with social responsibility standard ISO 26000 whose employee absen-

teeism was half that of their industry peers [6] — while other companies in their industry had a 6% absentee rate, theirs was at 3%. The company says their goal is to further reduce it to 1%, which clearly makes them a leader in their field. Hiring is an expensive

investment, in both dollars and time, and focusing on retaining talent can result in considerable gains to the bottom line in both productivity and quality of employee efforts.

- **Improved compliance** — According to the EPA, 247 new criminal cases were opened in 2020, which is approximately 30% more than 2019 [7]. Because of the year-after-year increase in environmental enforcement, it is more critical than ever for management to have a plan for environmental compliance.
- **General benefits** — Considering the poll among businesses to gain feedback on the benefits of an ISO 14001 environmental management system, the general benefits of such systems are clear, as shown in Figure 3 [4].

Regardless of the size of a company, there is extreme value in implementing a full ESG program, and it is worth noting that only a fraction of the benefits have been identified. Therefore, if you want to improve how your business is operated, engage your team into cost-saving initiatives, increase employee retention, and add to your bottom line, it’s time to get started on ESG.

Supercharge your ESG launch

The idea of “social responsibility” and using investments to enable social change started with the trade unions and pension funds in the 1950s and 1960s with the concept really taking off by the 1970s. Since then, the idea of social responsibility has evolved into what we know as ESG today. There are two important challenges of ESG that businesses need

to address once a decision has been made to pursue this type of business management style. First, the company has to define “ethical behavior.” Secondly, enough momentum must be created to effectively launch the program.

Ethical behavior. Anyone who has studied ethics can attest to the fact that there are many different perspectives and frameworks used to determine if an action is “ethical.” ISO 26000: Guidance on Social Responsibility, section 4.4 establishes, “an organization should behave ethically.” This leaves a lot of room for interpretation. Fortunately, the standard goes on to both define the terms specifically and explains, “An organization’s behavior should be based on the values of honesty, equity and integrity. These values imply a concern for people, animals and the environment and a commitment to address the impact of its activities and decisions on stakeholders’ interests” [8]. The standard further describes how an organization should actively promote the ethical behavior associated with implementing an ESG program. Of course, it’s the “how to” that is the challenge, because the standard has numerous different areas that all must be implemented.

Creating momentum

Implementing an ESG program is a major commitment that will impact how a business operates and makes decisions. Because of the magnitude of the effort, it is important to quickly engage co-workers, vendors and suppliers to gain momentum as you begin the development and implementation process. The following sections describe a few simple actions to help gain initial momentum so the entire company supports the commitment of ESG when it comes time to fully implement the program.

Communication. Even before the formal decision to pursue an ESG-style management process, it is important to start establishing the values of your company by talking about them in meetings, emails, site visits, client meetings and so on. These are all valuable opportunities to get people talking about the fundamentals of an ESG program, which should center around a concern for people, animals and the

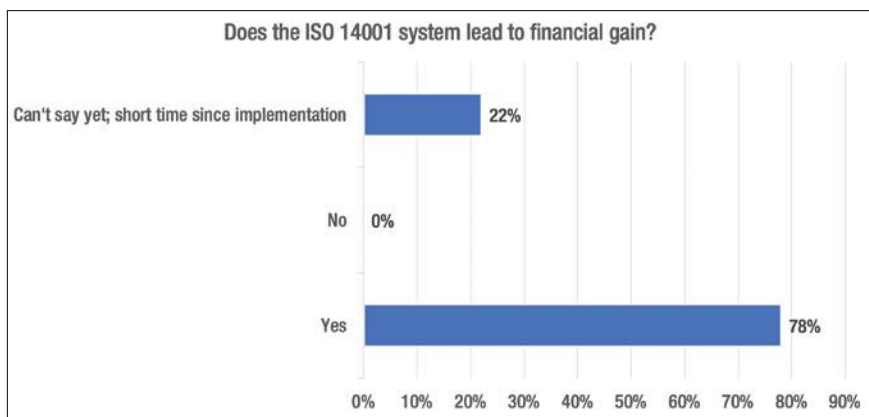


FIGURE 2. The vast majority of companies polled reported that they experienced financial gains after formally implementing the ISO 14001 system (based on survey data from Ref. 4)

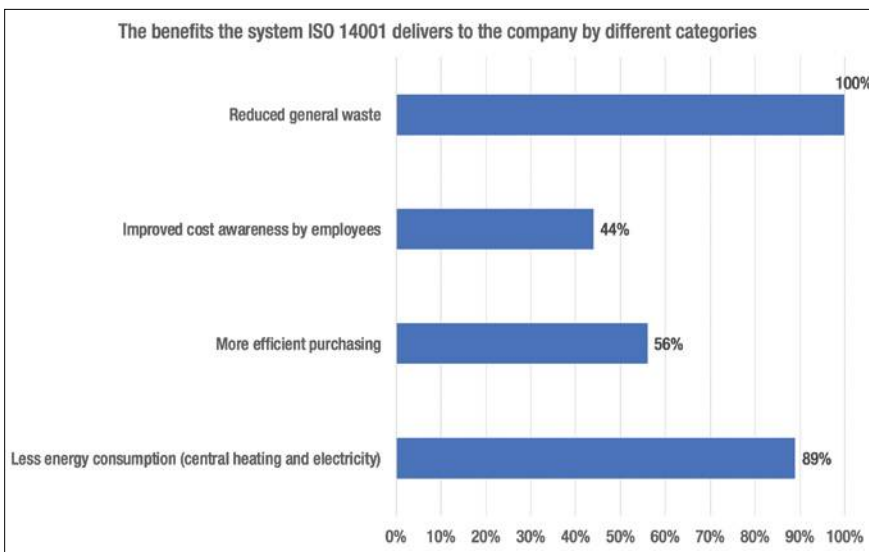


FIGURE 3. After adopting a formal environmental-management strategy governed by ISO 14001, reduced waste and improved energy usage were among the reported benefits (based on survey data from Ref. 4)

environment. It is also a great way to lay the foundations of a strong company culture. In addition, it helps to engage employees with these philosophies, because employees will also help to project the organization's goals and vision.

Awareness. Creating awareness campaigns throughout an organization is a simple and inexpensive way to build upon initial steps taken to start the ESG conversation. As you begin developing the ESG program, do so in a manner that is transparent throughout the organization. Let your team know the status, challenges, successes and how to contribute ideas to the implementation team. This should include, not only your company, but also your suppliers and vendors. Lastly, include signs, posters and email signature blocks that keep ESG on the forefront of everyone's mind. These small measures can go a long way in cre-

ating excitement and continuing forward momentum.

Engagement. The statement "It's just another management idea" should never be spoken by your team. Not only should efforts be transparent and well communicated, steps should be taken to actively engage employees at all levels of the organization. This will provide much needed buy-in, feedback and incredible insight that will go well beyond the ESG program. Consider setting up committees at the different levels of the organization and formalizing them by establish areas of responsibility and levels of authority to take action. Where a senior executive meeting may set the direction of the program, a management committee meeting can provide the program development and a facility employee committee can provide practical implementation tools. It is important to have each committee keep meeting

minutes so that they can be shared throughout the organization to further enhance communication.

These three ways to create momentum will provide you with the needed inertia to launch the ESG program. They will also increase employee engagement and provide a solid foundation to begin developing your company's long-term success.

ESG success stories

Implementing an ESG program is a large commitment that will challenge all levels of the organization to actively demonstrate their personal values. This is a large undertaking that should not be underestimated when being evaluated for your organization. With that said, your organization will enjoy the many benefits discussed once the hard work of implementation has been completed. Below are a few success stories to consider.

Marketing firm SYKES Costa Rica started implementing an ISO 14001 program in 2008. During that time, the team began to actively manage the use of energy, water, materials, waste protocols and recycling programs in an effort to minimize the impacts from its operations on the environment. In 2018, the company achieved formal ISO 14001 certification, but that is only the beginning. Since then, the group has also achieved certifications in ISO 14064 for greenhouse-gas management and ISO 50001 for energy management, and it became carbon-neutral certified. One of the most impressive aspects of SYKES' success is that, "In the past five years, the company's workforce increased by 30% to more than 5,500 employees, while the non-recoverable waste decreased from 87% to 63%" [9]. The decreased waste is an impressive accomplishment and it is equally impressive that decreased waste results in an overall reduction in material costs.

A second benefit, which is often overlooked, is the social aspect associated with an ESG program. Not only do these benefits impact the greater community, but they also provide participants with a much stronger and more competitive company. The Society for Human Resource Management published an

article entitled Closing the Gender Pay Gap that highlighted how, “Reducing the pay gap helps in the hiring, promotion and retention of women, and in turn results in more female leaders, ... And more women in leadership means better decision-making and financial results for companies, according to a 2017 study by McKinsey & Co. It found that businesses in the top quartile of gender diversity within their executive ranks were 21% more likely to see above-average profitability” [10].

Health and safety costs are tangible savings that should be easily quantifiable by your company’s accounting department or bookkeeper. However, the ISO 45001 Academy highlights another aspect of financial benefit achieved by implementing another socially responsible initiative, a safety management system [11]. The blog highlights that, “Satisfied employees who feel valued are obviously less likely to leave than those who don’t. Estimations of the cost of training new employees can vary, but it is generally accepted that this cost equals something between the equivalent of 6 to 9 months’ salary to train a new staff member...” The Satell Institute published a study that highlights a 50% reduction in employee turnover as a result of implementing a corporate social responsibility (CSR) program [12].

Additionally, *Parcel*, an online supply-chain magazine, made a powerful statement when it stated that, “Poor transparency, inadequate corporate governance, and weak rule of law create an uncertain foundation for supply-chain transactions when a weak regulatory and governing environment exists in an organization” [13]. This highlights the need for strong corporate governance, which is one of the principal tenants of an effective ESG program. Further underlining this statement, agribusiness Bunge suffered financially as a result of poor supply-chain control, according to a *Harvard Business Review* report [14]. When flooding hit Thailand in 2011, the company lost \$56 million in one quarter because of the interruption to the company’s supply chain and lack of governance over that part of the

business. In contrast, other companies made investments in the farmers who supplied key ingredients for their products, and not only increased the reliability of the suppliers, but also increased the overall harvest yields, which lowered the cost to the company while increasing profits to the local farmers.

The ESG success stories highlighted here are excellent examples of how managing a company’s impact to people and the planet can positively impact profits. These examples are just the beginning of the rewards companies receive from implementing an ESG program. ■

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Author



Curtis Shakotko is technical consulting principal at OneSource EHS LLC (Email: curtis.shakotko@onesourceehs.com). He leads the group’s Environmental and Process Safety Consulting practices. He has a combination of over 25 years of practical, regulatory and technical management experience. He has led the organization

to successfully developing strong internal controls to maximize quality and efficiency of project work, while driving organizational discipline to maintain a competitive advantage within this industry. He is a licensed professional engineer (PE) and also holds an M.B.A. degree from Regis University in Colorado.

Open Process Automation is Gaining Sustainable Momentum

Digital transformation in the chemical process industries demands open architecture, enterprise-wide interoperability and a focus on sustainability. Progress discussed here is moving the industry in that direction

Kevin Finnan
Yokogawa

Many companies in the chemical process industries (CPI) are currently pursuing digital transformations to accelerate their business strategies. Enabled by a broad range of digital technologies, such as sweeping transformations empower people, optimize processes and automate systems to radically reorient business performance.

In the face of multiple, evolving market dynamics, companies have found that engaging in the digital transformation is necessary to provide the agility to compete and thrive in “new normal” ecosystems. The transformed enterprises can respond more rapidly to new user requirements, supply chain issues and market disruptions.

Achieving the agility and responsiveness that is the hallmark of digital-transformation initiatives often requires merging disciplines that formerly operated in silos. For instance, operations technology (OT) personnel find their organizations requiring tight integration with information technology (IT) staff in newly collaborative, highly data-intensive environments that have deployed real-time analytics, artificial intelligence (AI), cloud- and edge-computing technologies, digital twins and industrial internet of things (IIoT) tools.

Under pressure to reduce capital and lifecycle costs and improve their profitability, the OT staff has recognized that proprietary technologies present serious obstacles to digital transformations. Closed systems, such as those used for process automation, are expensive to upgrade and maintain. Upgrades can also be risky. Many operations forego migrating or refreshing their technology in

order to avoid the risk of prolonged downtime. As the system ages, other risks increase. These include hardware failures and changes in technology that prevent replacement.

There is another risk that cybersecurity cannot be updated to safely protect operations, assets and capital investments. Legacy systems become more challenging to integrate with current or future best-in-class technologies, such as those required to digitally transform. Digital transformations demand enterprise-wide interoperability, cybersecurity, agility and sustainability. Networks with customized integration that connect formerly siloed, proprietary systems are expensive, hard to utilize and hence become unsustainable.

The “great crew change” and the incoming workforce that tends to be younger and more computer-knowledgeable are always key enablers for digital transformations. Digital transformation program teams have found that technically savvy newcomers, who are accustomed to interoperable consumer products, take a very dim view of closed, proprietary systems in the workplace.

In light of this situation, the Open Process Automation Forum (OPAF) of the Open Group (www.opengroup.org) began working in 2016 to develop a set of Open Process Automation Standards (O-PAS). The Open Group is a global consortium that helps organizations achieve business objectives through technology standards. OPAF is an international forum of end users, system integrators, suppliers, academia and standards organizations working together to develop a standards-based, open, secure and interoperable process automation architecture. An open architecture and interoperability supported by industry standards provide

a solid and necessary path forward for digital transformations leading to system sustainability.

‘Standard of standards’

OPAF’s open process automation “standard of standards” ensures that future automation systems adopt and reinforce standards that achieve true interoperability of hardware and software while also providing built-in security, future-proof innovation and greatly simplified migration. These will enable end-users to realize much more value from their operations.

The idea of a standard of standards is the result of OPAF’s effort to leverage work already accomplished by a broad variety of organizations. Industry standards reflect an industry-wide consensus and form a solid, sustainable foundation for open systems. Therefore, wherever possible, O-PAS references existing standards from the most well-established, global organizations — those standards that are most likely to endure in the long term.

To close the gaps, OPAF has been working with the appropriate groups to update their standards or incorporate O-PAS requirements. OPAF has established liaisons with organizations such as the Control System Integrators Association (CSIA), Industrial Internet Consortium (IIC), International Society of Automation (ISA), NAMUR and the OPC Foundation.

Global standards are referenced throughout O-PAS. The technical architecture is based on IEC 62264 (ISA-95), alarm management on IEC 62862 (ISA-18.2), and integral cybersecurity on IEC 62443 (ISA-99). OPAF is also in discussions with the ISA Security Compliance Institute (ISCI) as an ISA/IEC 62443 validation authority.

O-PAS incorporates IEC 61131-3

function blocks, IEC 61499 event-based programming, IEC 62714 (AutomationML) for control applications, and DMTF Redfish for systems management. The connectivity framework, information and exchange models are based on IEC 62541 (OPC UA). Notably, the OPC Foundation has taken a step beyond the liaison agreement by joining OPAF as a member.

The benefits of standards deployment are far-reaching. The latest O-PAS version tightly defines and controls system data and requires uniform alarm reporting. Yokogawa's Dave Emerson, who is co-chair of OPAF's Enterprise Architecture Working Group, explains it by saying that in the past, each supplier used to publish alarms and event conditions in different formats, so users had to waste time with different types of messages. Now, consistent reporting means they can save time.

Scope and vision

O-PAS enables the development of systems composed of cohesive, loosely coupled, severable functional elements from independent suppliers. The elements are easily integrated via a structured modular architecture. O-PAS does not define the functional intellectual property (IP) in the products; the IP can remain proprietary to their suppliers. Instead, the objective is to define open standard interfaces. Interoperability is the key.

As shown in Figure 1, the O-PAS scope encompasses today's distributed control systems (DCS) and programmable logic controllers (PLC) for continuous and hybrid process industries. Out-of-scope are business systems and communication protocols between the input-output (I/O) and field instruments. OPAF also decided that safety instrumented systems (SIS) would be out-of-scope because there must be separate and independent combinations of sensors, logic solvers and final elements to achieve required safety integrity levels per the ISA84 and IEC 61511 standards.

An Open Process Automation (OPA) system is a software-defined control system. It is an open system with all the benefits of a traditional DCS or PLC system and more — but without the limitations resulting

from supplier hardware or software locking. End-users or integrators can design, operate and expand functions with a wide range of interoperable software and hardware capabilities from multiple suppliers and technologies.

By decoupling hardware and software and employing a service-oriented architecture, the necessary software functions can be situated in many different locations or processors. Not only can software applications run in most hardware, but they can also access any I/O to increase flexibility when designing a system.

Figure 2 shows a reference OPA architecture with O-PAS-compliant products and non-compliant or legacy products. A realistic scenario for many end-users is to "start small," using a hybrid system with a combination of OPA and proprietary components, followed by a steady transition from the legacy system to one that is completely open, interoperable and sustainable.

In an OPA system, most applications and workloads are containerized to run flexibly and in an interoperable manner, utilizing the O-PAS Communication Framework (OCF). The OCF provides a secure, standardized interconnection between O-PAS-compliant software functions. Based on the OPC Unified Architecture (UA), the OCF provides protected, standards-based, reliable data transport.

The distributed control node (DCN) is considered the fundamental O-PAS building block. An edge

device, it is a scalable controller, I/O or gateway device that can handle I/O and computing functions. Since hardware and control software are decoupled, the exact function of a particular DCN is up to the system architect. A DCN consists of hardware and system software that enables it to communicate on the OCF and run control software. A DCN can be hardware or virtual. A system can use a few or several thousand DCNs.

Device suppliers are allowing end-users to add, configure and program the software components of the hardware devices based on their requirements. In order to make the device visible as a DCN to the rest of the system, the O-PAS Communication Interface (OCI) software layer can be added as an embedded application to any such non-compliant, flexible architecture-based device.

The advanced computing platform (ACP) enables DCN functionality, but includes scalable computing components, such as CPU cores, memory and storage media to handle applications that require more resources than are typically available in a DCN. ACPs may also be used for applications that cannot be easily or efficiently distributed. ACPs can be on-premise servers or in a cloud

Gaining momentum

O-PAS is gaining momentum on a daily basis. Don Bartusiak, co-chair of OPAF and president of Collaborative Systems Integration has reported that OPAF has 110 organizational members, as of the beginning of

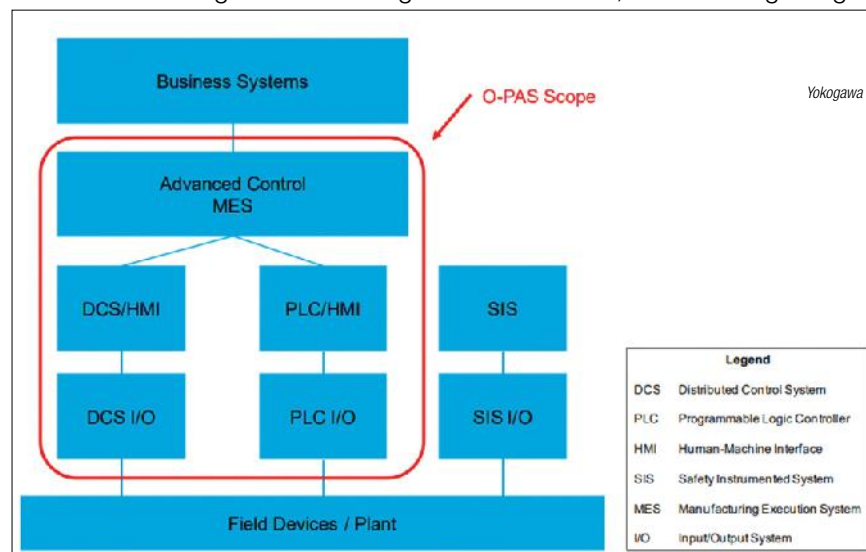


FIGURE 1. The scope of the O-PAS includes the DCS, PLC and manufacturing execution system. Business systems, safety instrumented systems and field devices are outside the O-PAS scope

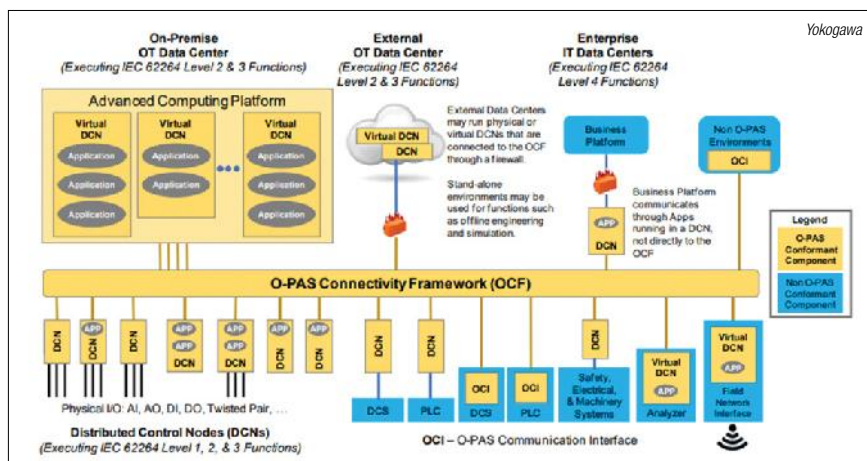


FIGURE 2. An O-PAS reference architecture shows a hybrid system that consists of O-PAS-compliant products as well as legacy or non-compliant products

2023, including 22 operating companies, six of the major DCS suppliers, and a host of other suppliers and system integrators.

There are well-established O-PAS demonstrators and testbeds at BASF, Dow Chemical, and Georgia Pacific, plus testbed collaborations between Aramco and Schneider in the Middle East and ExxonMobil with Yokogawa in The Woodlands, Texas.

In a new development, ExxonMobil has announced a major step beyond its testbed, with an O-PAS field trial in an actual plant process, scheduled for commissioning in 2023. Shell and Petronas also recently announced new testbed projects, while Evonik announced a project with Collaborative Systems Integration.

Bartusiak and OPAF leaders have indicated that several real-world prototype projects are producing vital know-how from which everyone can benefit, especially when they seek to scale up interoperable systems and process applications in the future.

In addition to learning from these projects, which are sponsored by industry-leading companies, there are other ways for smaller prospective users to expedite their involvement. Recently, a number of OPAF-member suppliers and system integrators formed the Coalition for Open Process Automation (COPA). The coalition includes Codesys, CPlane.ai, CSI, Phoenix Contact, Smar, and the University of Western Australia. To advance the starting point for smaller end-users, COPA has developed a “QuickStart” training program for control system interoperability using O-PAS.

Another recent development is the

publication, in December 2021, of the O-PAS Business Guide, Version 2.0, which provides a value proposition for O-PAS and describes how prospective participants can formulate a business case.

OPAF envisions a business ecosystem of end-users, system integrators, hardware and software product suppliers, and solution and service providers. Roles and responsibilities are defined for procurement, design, development, integration, deployment, operation and sustainment of O-PAS-certified products. A company can perform one or more roles in the ecosystem. OPAF also defines how the business models of current stakeholders will be impacted by OPA interoperability.

Pushback from system suppliers who might consider OPA a threat to their proprietary IP has been mild. After all, automation suppliers are not dinosaurs stuck in the 1970s. They have opened up their architectures with commercial off-the-shelf (COTS) hardware and software such as Microsoft Windows, broad communication support such as Ethernet and field device networks, and virtualized platforms.

Still, significant proprietary content remains. Manufacturers who must be agile, responsive and innovative to compete on a daily basis in emerging business ecosystems consider that risky. Also, despite a highly regarded track record in terms of user responsiveness, dependence on closed system suppliers is considered risky in markets requiring agility.

Proprietary system upgrades are expensive, and even in a case where

a system supplier offers a great deal in one instance, the risk still exists that the next upgrade will be expensive. And the downtime risk still remains, as well. Although a recent partnership between a major offshore oil producer and a leading automation company recently accomplished a broad technology refresh with no downtime, this type of feat is considered very innovative. Open architecture will allow the “no downtime technology refresh” to be the standard practice.

Concerns have been raised that OPA could undermine the main automation contractor (MAC) concept, in which major system suppliers offer the advantage of deep knowledge of their own products. But the MAC concept has evolved significantly beyond that. Recent MAC projects have included third-party content on a large scale. For example, the author's company has managed procurement, IT and instrumentation ranging from analyzers to valves. Given that sort of experience with proprietary, third-party platforms, it could be easily argued that OPA will greatly simplify project engineering. A broad range of systems integrator companies have agreed with this idea.

Many end-users also feel that open architectures and interoperability are necessary to support the environmental, social and governance (ESG) objectives to which they are striving in pursuit of their sustainability goals. OPA is not a matter of if, it is a matter of when. As OPA becomes mainstream, the vision and capabilities expand and the players in the space gain momentum. Businesses that embrace this technology will adroitly define the industry pivots instead of trying to catch up to them.

Edited by Scott Jenkins

Author



Kevin Finnan is a market intelligence and strategy advisor at Yokogawa Corp. of America (12530 West Airport Boulevard, Sugar Land, TX 77478; Email: kevin.finnan@yokogawa.com). Finnan was previously an independent consultant, as well as vice president of marketing for CSE-Semaphore, and director of marketing at Bristol Babcock. He has over 30 years of experience in a variety of vertical markets and has launched more than 40 products in automation and measurement technologies.

Reducing Soil-Side Corrosion in Aboveground Storage Tanks

Potential maintenance and repair cost savings are significant when employing vapor corrosion inhibitors either as a standalone mitigation technique, or as a complement to conventional cathodic protection methods, in aboveground storage tanks

Tim Whited

MESA Products

Julie Holmquist and Ana Juraga

Cortec Corp.

Mitigation of external corrosion on the bottoms of aboveground storage tanks (ASTs) can have a major impact on overall safety and asset repair costs. Given the critical nature of tank integrity for ASTs that hold hydrocarbons or other hazardous materials (Figure 1), periodic inspections are done to check tank-bottom integrity. Due to the time- and labor-intensive process of draining the tank products and cleaning sludge out of ASTs to prepare for out-of-service API 653 inspections — a standard developed by the American Petroleum Institute providing the most definitive data source for evaluating AST corrosion-mitigation effectiveness — operators are working diligently to extend inspection intervals from 10 years to 20 years. Tank owners must utilize all protective mechanisms that will give them sufficient confidence to do so. Tank owners and operators have multiple reasons and motivations to employ additional methods of corrosion protection

to supplement, and sometimes replace, the industry standard method, cathodic protection (CP).

For many years, a vapor corrosion-inhibitor technology, CorroLogic VpCI, has been under examination, both as a standalone AST corrosion-mitigation solution, and as a complementary solution used in conjunction with CP. Recent data from a tank in Cushing, Okla., provide an example of a direct correlation between corrosion reduction and the use of CorroLogic VpCI.

The soil-side corrosion problem

AST bottoms are typically uncoated and are located in contact with a perfect environment to promote corrosion due to a multitude of factors. Sand tank pads can also foster microbiologically induced corrosion (MIC). In some regions, such as the Middle East, the sand often contains high levels of minerals or corrosive salts (Sabkha soil) that exacerbate the corrosion problem. Sometimes, corrosion occurs even when appropriate preventative measures are taken, as was the case at the Cushing crude-oil terminal.

The tank in question was 125 ft (38 m) in diameter and had received a completely new floor in 2011. An annular ring-type impressed-current CP system was installed 1 ft (30 cm) below the floor to mitigate soil-side corrosion. This was a mixed metal-oxide (MMO) concentric-ring anode system with anodes spaced every 5

ft (1.5 m) for a total anode length of 2,652 ft (808 m). The rectifier rating was 30 V and 30 A. The CP system was commissioned in 2012 and operated continuously except for periods of de-energization required for terminal operations.

Despite these standard precautions, an unwelcome surprise presented itself three years after tank-floor replacement. During an out-of-service API 653 tank inspection in 2014, a floor scan identified significant soil-side corrosion. Using magnetic flux leakage (MFL) to scan 88% of the tank floor, inspectors found a total of 115 corrosion indications at a remaining wall thickness of 0.2 in. (5.08 mm) or less in 0.25-in. (6.35 mm) plates. The thinnest corrosion indication was found at 0.150 in. (3.81 mm). Soil samples taken at this time also indicated that MIC could be a concern. The corrosion indications were addressed accordingly by replacing or patching the floor wherever needed. However, a decision was made to supplement the CP system with CorroLogic VpCI technology and compare the results at the next tank inspection five years later.

The protection mechanism

CorroLogic VpCI technology offers protection for AST bottoms through vapor-phase action. VpCI is a vapor-phase corrosion inhibitor — a chemistry that can vaporize from a solid state, such as a powder, or liquid solution, such as a slurry, into a protective vapor. These vapors diffuse throughout enclosed spaces, enabling them to access hard-to-reach void spaces. The vapors have an affinity to metal, where they adsorb and form a protective molecular layer that inhibits the natural corrosion reaction in the presence of



FIGURE 1. Aboveground storage tanks can experience severe corrosion, and special care must be taken to avoid damage in tanks holding hydrocarbons or other hazardous materials

TABLE 1. CP OPERATION DATA, RECTIFIER OUTPUT: 2012–2019

Dates	October 4, 2012–June 3, 2014	June 4, 2014–June 23, 2019
Volts	5.0–5.7	5.0–5.7
Amps	20.5–30.3	20.0–33.0
Tank-floor current density, mA/ft ²	1.7–2.5	1.6–2.7

metal, oxygen and an electrolyte or other corrosives.

The Cushing terminal tank project presented an excellent opportunity to evaluate the effectiveness of CorroLogic VpCI. In 2014, the tank operator contracted MESA Products to apply CorroLogic powder. The powder was mixed with water, and the resulting 1,500 gal (5,678 L) of slurry were applied through the floor via eleven 0.75-in. (19-mm) temporary injection ports in the floor plates (136 gal injected at each port). A corrosion-monitoring system comprising five electrical-resistance (ER) probes was also installed below the tank bottom. The same CP system used since 2012 was turned on again. Rectifier output data are shown in Table 1.

The results of MFL scanning from the June 2019 API 653 inspection five years after the injection of CorroLogic VpCI were significant. This time, 92% of the tank bottom was scanned. The remaining thickness threshold was 0.21 in. (5 mm). Previous corrosion indications from the 2014 MFL scan were no longer in play due to repair or patching. It is therefore noteworthy that the 2019 inspection revealed only 11 corrosion indications, substantially fewer than the 115 total corrosion indications detected in

from a range of 16.7 to 33.3 mm per year (mil/yr, or mpy) over the initial three-year period to a range of 6.3 to 7.5 mpy in 2019. Table 2 compares the results of the 2014 inspection with those from 2019, showing significantly fewer corrosion indications.

Such results demonstrate an effective solution for drastically reducing corrosion rates through the addition of CorroLogic VpCI to the tank-bottom protection equation. It was very significant that the 2019 inspection only identified 11 corrosion indications following the application of CorroLogic VpCI in 2014. This provided the confidence needed for the terminal operator to have MESA perform additional CorroLogic VpCI installations on tanks taken out of service for inspection. This project also provided significant data that VpCI and CP interacted well together with an overall result of significantly less external tank-bottom corrosion. A further observation is that, since 2014 sand analysis identified the possibility for MIC, it is reasonable to assume that the CorroLogic VpCI chemistry and application method played a role in mitigating this problem.

The road to protection

The Cushing terminal tank project is an excellent example of how CP

2014 after three years of CP-only protection. Average rates of metal loss dropped

can be supplemented with CorroLogic VpCI to counteract the perennial issue of external corrosion on AST bottoms. CorroLogic VpCI is a relatively non-invasive technology that can be applied at any stage of a tank's service life to provide corrosion protection as a standalone solution, or as a supplement to CP. When properly applied, CorroLogic VpCI technology can potentially reduce the frequency of repairs and even inspections, which themselves are time-consuming and expensive (although costs vary depending on tank diameter, cleaning out crude oil sludge for inspection alone can easily exceed \$1 million for larger crude-oil storage tanks). Finally, CorroLogic VpCI offers an additional means of avoiding the danger of tank-floor bottom leaks and failures, as well as the need for premature tank-bottom replacement, which can incur costs easily reaching the million-dollar range. Corrosion prevention is clearly preferable to performing repairs, and at the Cushing oil terminal, CorroLogic has opened up a new road to slow the overall soil-side corrosion process and extend tank service life. ■

Edited by Mary Page Bailey

Authors



Tim Whited (Email: tim.whited@mesaproducts.com) is an engineering specialist with MESA Products. He has extensive experience with corrosion control in the oil-and-gas industry, especially in the area of AST bottom protection, and holds special certifications through the Association for Materials Protection and Performance (AMPP, formerly NACE), including NACE CP Specialist #3245 and NACE Impact Plus Navigator #3. He is currently the document project manager of the AMPP committee finalizing Standard SP21474 on the "External Corrosion Control of On-Grade Carbon-Steel Storage-Tank Bottoms."



Ana Juraga Oluic (Email: ana.juraga@ecocortec.hr) is corporate communications manager at Cortec Corp. She has been a content writer at Cortec for 10 years. Besides dealing with media relations, she collaborates with Cortec's engineers and chemists in creating informative technical content.



Julie Holmquist (Email: jholmquist@cortecvci.com) has been a content writer at Cortec Corp. for more than seven years. She specializes in writing about corrosion-inhibiting technology for concrete, electronics, manufacturing, oil-and-gas, and many other industries.

TABLE 2. CORROSION INDICATIONS AND MPY FROM 2014 AND 2019 CUSHING TERMINAL TANK INSPECTIONS

2014 inspection indications, 3 years after construction			2019 inspection indications, 5 years after VpCI application		
Remaining thickness	Total number of corrosion indications	Average metal loss over 3-yr period, mpy	Remaining thickness	Total number of corrosion indications	Average metal loss over 8-yr period, mpy
0.200	67	16.7	0.200	10	6.3
0.195	11	18.3	0.195	0	n/a
0.190	26	20.0	0.190	1	7.5
0.185	3	21.7	0.185	0	n/a
0.180	5	23.3	0.180	0	n/a
0.175	1	25.0	0.175	0	n/a
0.160	1	30.0	0.160	0	n/a
0.150	1	33.3	0.150	0	n/a
Totals	115		Totals	11	

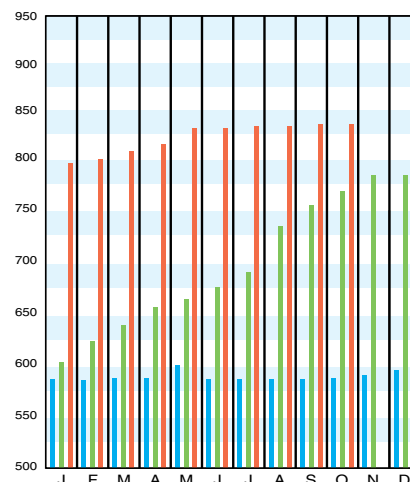
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Oct. '22 Prelim.	Sept. '22 Final	Oct. '21 Final
CE Index	816.3	821.3	761.4
Equipment	1034.3	1,042.1	956.4
Heat exchangers & tanks	865.7	872.2	816.7
Process machinery	1,040.2	1,047.5	962.6
Pipe, valves & fittings	1,462.3	1,478.1	1,361.0
Process instruments	549.6	556.8	559.8
Pumps & compressors	1,321.8	1,311.6	1,178.1
Electrical equipment	781.1	784.5	644.5
Structural supports & misc.	1,160.6	1,169.8	1,044.6
Construction labor	362.8	360.9	350.4
Buildings	807.9	813.7	782.0
Engineering & supervision	311.6	311.3	310.8

Annual Index:

2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8

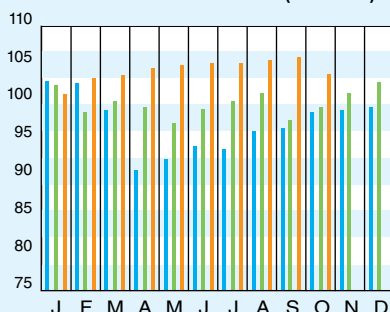


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76-77.)

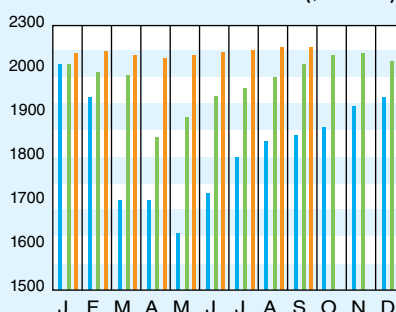
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	YEAR AGO
CPI output index (2017 = 100)	Oct. '22 = 101.0	Sept. '22 = 101.4	Aug. '22 = 101.2
CPI value of output, \$ billions	Sept. '22 = 2,181.5	Aug. '22 = 2,174.5	Sept. '21 = 1,855.9
CPI operating rate, %	Oct. '22 = 81.5	Sept. '22 = 81.8	Oct. '21 = 81.3
Producer prices, industrial chemicals (1982 = 100)	Oct. '22 = 349.1	Sept. '22 = 352.9	Aug. '22 = 358.4
Industrial Production in Manufacturing (2017 = 100)*	Oct. '22 = 102.3	Sept. '22 = 102.1	Aug. '22 = 101.9
Hourly earnings index, chemical & allied products (1992 = 100)	Oct. '22 = 202.7	Sept. '22 = 204.7	Aug. '22 = 199.8
Productivity index, chemicals & allied products (1992 = 100)	Oct. '22 = 92.7	Sept. '22 = 92.3	Aug. '22 = 93.4
			Oct. '21 = 96.3

CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE (\$ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.

†For the current month's CPI output index values, the base year was changed from 2012 to 2017

Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the CE Plant Cost Index (CEPCI; top) for October 2022 (most recent available) fell for the fourth consecutive month, following a long string of monthly increases between November 2020 and June 2022. For the October preliminary data, the decrease was driven by the Equipment and Buildings subindices, which both fell, while the Construction Labor and Engineering & Supervision subindices saw small rises. The current CEPCI value now sits at 7.2% higher than the corresponding value from October 2021. Meanwhile, the Current Business Indicators (middle) show decreases in the CPI output index and the CPI operating rate for October 2022, and an increase in the CPI value of output for September 2022.